

**Cycloalkyl-substituted alkanolic acid derivatives, processes for their  
5 preparation and their use as pharmaceuticals**

Description

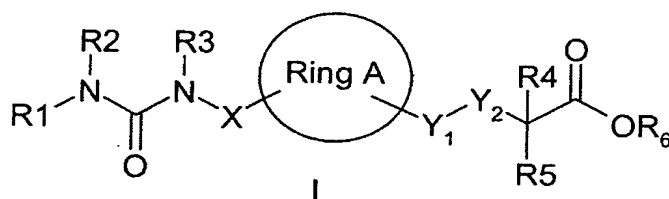
10 The invention relates to arylcycloalkyl-substituted alkanolic acid derivatives and to their physiologically acceptable salts and physiologically functional derivatives.

Compounds of a similar structure have already been described in the prior art for the treatment of hyperlipidemia and diabetes (WO 2000/64876).

15 The invention was based on the object of providing compounds which permit therapeutically utilizable modulation of lipid and/or carbohydrate metabolism and are thus suitable for the prevention and/or treatment of diseases such as type 2 diabetes and atherosclerosis and the diverse sequelae thereof.

20 A series of compounds which modulate the activity of PPA receptors has surprisingly been found. The compounds are suitable in particular for activating PPARalpha and PPARgamma, it being possible for the extent of the relative activation to vary depending on the compounds.

25 Accordingly, the invention relates to compounds of the formula I



wherein

- Ring A is (C<sub>3</sub>-C<sub>8</sub>)-cycloalkanediyl or (C<sub>3</sub>-C<sub>8</sub>)-cycloalkenediyl, wherein one or more carbon atoms in said (C<sub>3</sub>-C<sub>8</sub>)-cycloalkane- and (C<sub>3</sub>-C<sub>8</sub>)-cycloalkenediyl groups may be replaced by oxygen atoms;
- 5 R1, R2 are each independently H, (C<sub>1</sub>-C<sub>6</sub>)-alkyl, (C<sub>3</sub>-C<sub>8</sub>)-cycloalkyl or (C<sub>6</sub>-C<sub>10</sub>)-aryl;
- 10 R3 is (C<sub>3</sub>-C<sub>6</sub>)-cycloalkyl or (C<sub>1</sub>-C<sub>12</sub>)-alkyl, each of which is optionally substituted by (C<sub>6</sub>-C<sub>10</sub>)-aryl, (C<sub>5</sub>-C<sub>6</sub>)-heteroaryl or (C<sub>3</sub>-C<sub>6</sub>)-cycloalkyl, and wherein said (C<sub>6</sub>-C<sub>10</sub>)-aryl, (C<sub>5</sub>-C<sub>6</sub>)-heteroaryl and (C<sub>3</sub>-C<sub>6</sub>)-cycloalkyl substituents are themselves optionally substituted by (C<sub>1</sub>-C<sub>6</sub>)-alkyl, (C<sub>1</sub>-C<sub>6</sub>)-alkoxy, Cl, Br, I, CO-(C<sub>1</sub>-C<sub>6</sub>)-alkyl, CO-O(C<sub>1</sub>-C<sub>6</sub>)-alkyl, CO-NH(C<sub>1</sub>-C<sub>6</sub>)-alkyl or CO-N((C<sub>1</sub>-C<sub>6</sub>)-alkyl)<sub>2</sub>;
- 15 X is (C<sub>1</sub>-C<sub>6</sub>)-alkanediyl, wherein one or more carbon atoms therein are optionally replaced by oxygen atoms;
- Y<sub>1</sub> is CO or a bond;
- 20 Y<sub>2</sub> is NH or (C<sub>1</sub>-C<sub>12</sub>)-alkanediyl wherein one or more carbon atoms therein are optionally replaced by oxygen atoms;
- R4 is (C<sub>1</sub>-C<sub>8</sub>)-alkyl;
- 25 R5 is H or (C<sub>1</sub>-C<sub>6</sub>)-alkyl;
- R6 is H;

and pharmaceutically acceptable salts thereof.

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Preference is given to compounds of the formula I wherein substituents X and Y<sub>1</sub> are bonded to the ring A in positions 1 and 3. (X – Ring A – Y<sub>1</sub>).

Preference is also given to compounds of the formula I in which

- Ring A is (C<sub>3</sub>-C<sub>8</sub>)-cycloalkane-1,3-diyl;
- 5 R1, R2 are each independently H, (C<sub>1</sub>-C<sub>6</sub>)-alkyl, (C<sub>3</sub>-C<sub>8</sub>)-cycloalkyl or (C<sub>6</sub>-C<sub>10</sub>)-aryl;
- R3 is (C<sub>1</sub>-C<sub>12</sub>)-cycloalkyl optionally substituted by phenyl, wherein said phenyl substituent is optionally substituted by (C<sub>1</sub>-C<sub>6</sub>)-alkyl;
- 10 X is (C<sub>1</sub>-C<sub>6</sub>)-alkanediyl wherein one carbon atom therein is optionally replaced by an oxygen atom;
- Y<sub>1</sub> is CO or a bond;
- 15 Y<sub>2</sub> is NH or (C<sub>1</sub>-C<sub>6</sub>)-alkanediyl wherein one carbon atom therein is optionally replaced by an oxygen atom;
- R4 is (C<sub>1</sub>-C<sub>8</sub>)-alkyl;
- 20 R5 is H or (C<sub>1</sub>-C<sub>6</sub>)-alkyl; and
- R6 is H.

Particular preference is given to compounds of the formula I in which

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- Ring A is cyclohexane-1,3-diyl;
- R1, R2 are each independently H, (C<sub>1</sub>-C<sub>6</sub>)-alkyl, (C<sub>3</sub>-C<sub>8</sub>)-cycloalkyl or phenyl;
- 30 R3 is (C<sub>1</sub>-C<sub>12</sub>)-alkyl optionally substituted by phenyl, wherein said phenyl substituent is optionally substituted by methyl;
- X is (C<sub>1</sub>-C<sub>6</sub>)-alkanediyl wherein the carbon atom adjacent to ring A is optionally replaced by an oxygen atom;

Y<sub>1</sub> is CO or a bond;

5 Y<sub>2</sub> is NH or (C<sub>1</sub>-C<sub>6</sub>)-alkanediyl wherein one carbon atom therein is optionally replaced by an oxygen atom;

R<sub>4</sub> is (C<sub>1</sub>-C<sub>8</sub>)-alkyl;

10 R<sub>5</sub> is H or (C<sub>1</sub>-C<sub>4</sub>)-alkyl; and

R<sub>6</sub> is H.

Very particular preference is given to compounds of the formula I

15 wherein

Ring A is cyclohexane-1,3-diyl;

20 R<sub>1</sub> is H;

R<sub>2</sub> is (C<sub>1</sub>-C<sub>6</sub>)-alkyl, (C<sub>3</sub>-C<sub>8</sub>)-cycloalkyl or phenyl;

25 R<sub>3</sub> is (C<sub>1</sub>-C<sub>8</sub>)-alkyl optionally substituted by phenyl, wherein said phenyl substituent is optionally substituted by methyl;

X is CH<sub>2</sub>CH<sub>2</sub>O;

Y<sub>1</sub> is CO or a bond;

30 Y<sub>2</sub> is NH or (C<sub>1</sub>-C<sub>4</sub>)-alkanediyl;

R<sub>4</sub> is (C<sub>1</sub>-C<sub>6</sub>)-alkyl;

R<sub>5</sub> is H or (C<sub>1</sub>-C<sub>4</sub>)-alkyl; and

R6 is H.

- 5 The bond to ring A may be either cis or trans, preference is given to the cis-bond.

This invention also encompasses all combinations of preferred aspects of the invention described herein.

- 10 The alkyl radicals in the substituents R1, R2, R3, R4, R5 and R6 may be either straight-chain or branched.

Aryl means an aromatic carbocyclic mono- or bicyclic ring system which comprises 6 to 10 atoms in the ring or rings.

15

Heteroaryl is a mono- or bicyclic aromatic ring system having 4 to 11 ring members, in which at least one atom in the ring system is a heteroatom from the series N, O and S.

- 20 The compounds of the formula I comprise at least two centers of asymmetry and may comprise more in addition. The compounds of the formula I may therefore exist in the form of their racemates, racemic mixtures, pure enantiomers, diastereomers and mixtures of diastereomers. The present invention encompasses all these isomeric forms of the compounds of the formula I. These  
25 isomeric forms can be obtained by known methods even if not specifically described in some cases.

- Pharmaceutically acceptable salts are, because their solubility in water is greater than that of the initial or basic compounds, particularly suitable for medical  
30 applications. These salts must have a pharmaceutically acceptable anion or cation. Suitable pharmaceutically acceptable acid addition salts of the compounds of the invention are salts of inorganic acids such as hydrochloric acid, hydrobromic, phosphoric, metaphosphoric, nitric and sulfuric acid, and of organic acids such as, for example, acetic acid, benzenesulfonic, benzoic, citric,

ethanesulfonic, fumaric, gluconic, glycolic, isethionic, lactic, lactobionic, maleic, malic, methanesulfonic, succinic, p-toluenesulfonic and tartaric acid. Suitable pharmaceutically acceptable basic salts are ammonium salts, alkali metal salts (such as sodium and potassium salts), alkaline earth metal salts (such as

5 magnesium and calcium salts), and salts of trometamol (2-amino-2-hydroxymethyl-1,3-propanediol), diethanolamine, lysine or ethylenediamine.

Salts with a pharmaceutically unacceptable anion such as, for example, trifluoroacetate likewise belong within the framework of the invention as useful

10 intermediates for the preparation or purification of pharmaceutically acceptable salts and/or for use in nontherapeutic, for example in vitro, applications.

As used herein, the following definitions apply:

15 "Patient" means a warm blooded animal, such as for example rat, mice, dogs, cats, guinea pigs, and primates such as humans.

"Treat" or "treating" means to alleviate symptoms, eliminate the causation of the symptoms either on a temporary or permanent basis, or to prevent or slow the

20 appearance of symptoms of the named disorder or condition.

"Therapeutically effective amount" means a quantity of the compound which is effective in treating the named disorder or condition.

25 "Pharmaceutically acceptable carrier" is a non-toxic solvent, dispersant, excipient, adjuvant or other material which is mixed with the active ingredient in order to permit the formation of a pharmaceutical composition, i.e., a dosage form capable of administration to the patient. One example of such a carrier is a pharmaceutically acceptable oil typically used for parenteral administration.

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The term "physiologically functional derivative" used herein refers to any physiologically tolerated derivative of a compound of the formula I of the invention, for example an ester, which on administration to a mammal such as, for example, a human is able to form (directly or indirectly) a compound of the formula I or an

active metabolite thereof.

Physiologically functional derivatives also include prodrugs of the compounds of the invention, as described, for example, in H. Okada et al., Chem. Pharm. Bull. 1994, 42, 57-61. Such prodrugs can be metabolized in vivo to a compound of the invention. These prodrugs may themselves be active or not.

The compounds of the invention may also exist in various polymorphous forms, for example as amorphous and crystalline polymorphous forms. All polymorphous forms of the compounds of the invention belong within the framework of the invention and are a further aspect of the invention.

All references to "compound(s) of formula I" hereinafter refer to compound(s) of the formula I as described above, and their salts, solvates and physiologically functional derivatives as described herein.

## Use

This invention relates further to the use of compounds of the formula I and their pharmaceutical compositions as PPAR ligands. The PPAR ligands of the invention are suitable as modulators of PPAR activity.

Peroxisome proliferator-activated receptors (PPAR) are transcription factors which can be activated by ligands and belong to the class of nuclear hormone receptors. There are three PPAR isoforms, PPARalpha, PPARgamma and PPARdelta, which are encoded by different genes (Peroxisome proliferator-activated receptor (PPAR): structure, mechanisms of activation and diverse functions: Motojima K, Cell Struct Funct. 1993 Oct; 18(5): 267-77).

Two variants of PPARgamma exist, PPARgamma<sub>1</sub> and gamma<sub>2</sub>, which are the result of alternative use of promoters and differential mRNA splicing (Vidal-Puig et al. J. Clin. Invest., 97:2553-2561, 1996). Different PPARs have different tissue distribution and modulate different physiological functions. The PPARs play a key role in various aspects of the regulation of a large number of genes, the products

of which genes are directly or indirectly crucially involved in lipid and carbohydrate metabolism. Thus, for example, PPARalpha receptors play an important part in the regulation of fatty acid catabolism or lipoprotein metabolism in the liver, while PPARgamma is crucially involved for example in regulating adipose cell

5 differentiation. In addition, however, PPARs are also involved in the regulation of many other physiological processes, including those which are not directly connected with carbohydrate or lipid metabolism. The activity of different PPARs can be modulated by various fatty acids, fatty acid derivatives and synthetic compounds to varying extents. For relevant reviews about functions, physiological effect and pathophysiology, see: Joel Berger et al., Annu. Rev. Med. 2002, 53, 409  
10 – 435; Timothy Wilson et al. J. Med. Chem., 2000, Vol. 43, No. 4, 527-550; Steven Kliewer et al., Recent Prog Horm Res. 2001; 56: 239-63.

The present invention relates to compounds of the formula I suitable for  
15 modulating the activity of PPARs, especially the activity of PPARalpha and PPARgamma. Depending on the modulation profile, the compounds of the formula I are suitable for the treatment, control and prophylaxis of the indications described hereinafter, and for a number of other pharmaceutical applications connected thereto (see, for example, Joel Berger et al., Annu. Rev. Med. 2002, 53, 409 –  
20 435; Timothy Wilson et al. J. Med. Chem., 2000, Vol. 43, No. 4, 527-550; Steven Kliewer et al., Recent Prog Horm Res. 2001; 56: 239-63; Jean-Charles Fruchart, Bart Staels and Patrick Duriez: PPARs, Metabolic Disease and Arteriosclerosis, Pharmacological Research, Vol. 44, No. 5, 345-52; 2001; Sander Kersten, Beatrice Desvergne & Walter Wahli: Roles of PPARs in health and disease,  
25 NATURE, VOL 405, 25 MAY 2000; 421-4; Ines Pineda Torra, Giulia Chinetti, Caroline Duval, Jean-Charles Fruchart and Bart Staels: Peroxisome proliferator-activated receptors: from transcriptional control to clinical practice, Curr Opin Lipidol 12: 2001, 245-254).

30 Compounds of this type are particularly suitable for the treatment and/or prevention of

1. - disorders of fatty acid metabolism and glucose utilization disorders
  - disorders in which insulin resistance is involved



2. Diabetes mellitus, especially type 2 diabetes, including the prevention of the sequelae associated therewith.

Particular aspects in this connection are

- 5     - hyperglycemia,
- improvement in insulin resistance,
- improvement in glucose tolerance,
- protection of the pancreatic  $\beta$  cells
- prevention of macro- and microvascular disorders
- 10    3. Dyslipidemias and their sequelae such as, for example, atherosclerosis, coronary heart disease, cerebrovascular disorders etc, especially those (but not restricted thereto) which are characterized by one or more of the following factors:
- high plasma triglyceride concentrations, high postprandial plasma
- 15       triglyceride concentrations,
- low HDL cholesterol concentrations
- low ApoA lipoprotein concentrations
- high LDL cholesterol concentrations
- small dense LDL cholesterol particles
- 20       - high ApoB lipoprotein concentrations
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- 4. Various other conditions which may be associated with the metabolic syndrome, such as:
- obesity (excess weight), including central obesity
- 25       - thromboses, hypercoagulable and prothrombotic states (arterial and venous)
- high blood pressure
- heart failure such as, for example (but not restricted thereto), following myocardial infarction, hypertensive heart disease or cardiomyopathy
- 30
- 5. Other disorders or conditions in which inflammatory reactions or cell differentiation may for example be involved are:
- atherosclerosis such as, for example (but not restricted thereto), coronary sclerosis including angina pectoris or myocardial infarction, stroke

- vascular restenosis or reocclusion
- chronic inflammatory bowel diseases such as, for example, Crohn's disease and ulcerative colitis
- pancreatitis
- 5 - other inflammatory states
- retinopathy
- adipose cell tumors
- lipomatous carcinomas such as, for example, liposarcomas
- 10 - solid tumors and neoplasms such as, for example (but not restricted thereto), carcinomas of the gastrointestinal tract, of the liver, of the biliary tract and of the pancreas, endocrine tumors, carcinomas of the lungs, of the kidneys and the urinary tract, of the genital tract, prostate carcinomas etc
- acute and chronic myeloproliferative disorders and lymphomas
- angiogenesis
- 15 - neurodegenerative disorders
- Alzheimer's disease
- multiple sclerosis
- Parkinson's disease
- erythemato-squamous dermatoses such as, for example, psoriasis
- 20 - acne vulgaris
- other skin disorders and dermatological conditions which are modulated by PPAR
- eczemas and neurodermitis
- dermatitis such as, for example, seborrheic dermatitis or photodermatitis
- 25 - keratitis and keratoses such as, for example, seborrheic keratoses, senile keratoses, actinic keratosis, photo-induced keratoses or keratosis follicularis
- keloids and keloid prophylaxis
- warts, including condylomata or condylomata acuminata
- human papilloma viral (HPV) infections such as, for example, venereal papillomata, viral warts such as, for example, molluscum contagiosum, leukoplakia
- 30 - papular dermatoses such as, for example, Lichen planus
- skin cancer such as, for example, basal-cell carcinomas, melanomas or cutaneous T-cell lymphomas

- localized benign epidermal tumors such as, for example, keratoderma, epidermal naevi
- chilblains
- high blood pressure
- 5     - syndrome X
- polycystic ovary syndrome (PCOS)
- asthma
- osteoarthritis
- lupus erythematosus (LE) or inflammatory rheumatic disorders such as, for
- 10     example, rheumatoid arthritis
- vasculitis
- wasting (cachexia)
- gout
- ischemia/reperfusion syndrome
- 15     - acute respiratory distress syndrome (ARDS)

## Formulations

20     The amount of a compound of formula I necessary to achieve the desired biological effect depends on a number of factors, for example the specific compound chosen, the intended use, the mode of administration and the clinical condition of the patient. The daily dose is generally in the range from 0.001 mg to 100 mg (typically from 0.01 mg to 50 mg) per day and per kilogram of bodyweight, for example 0.1-10 mg/kg/day. An intravenous dose may be, for example, in the

25     range from 0.001 mg to 1.0 mg/kg, which can suitably be administered as infusion of 10 ng to 100 ng per kilogram and per minute. Suitable infusion solutions for these purposes may contain, for example, from 0.1 ng to 10 mg, typically from 1 ng to 10 mg, per milliliter. Single doses may contain, for example, from 1 mg to 10 g of the active ingredient. Thus, ampules for injections may contain, for

30     example, from 1 mg to 100 mg, and single-dose formulations which can be administered orally, such as, for example, capsules or tablets, may contain, for example, from 0.05 to 1000 mg, typically from 0.5 to 600 mg. For the therapy of the abovementioned conditions, the compounds of formula I may be used as the compound itself, but they are preferably in the form of a pharmaceutical

composition with an acceptable carrier. The carrier must, of course, be acceptable in the sense that it is compatible with the other ingredients of the composition and is not harmful for the patient's health. The carrier may be a solid or a liquid or both and is preferably formulated with the compound as a single dose, for example as a tablet, which may contain from 0.05% to 95% by weight of the active ingredient. Other pharmaceutically active substances may likewise be present, including other compounds of formula I. The pharmaceutical compositions of the invention can be produced by one of the known pharmaceutical methods, which essentially consist of mixing the ingredients with pharmacologically acceptable carriers and/or excipients.

Pharmaceutical compositions of the invention are those suitable for oral, rectal, topical, peroral (for example sublingual) and parenteral (for example subcutaneous, intramuscular, intradermal or intravenous) administration, although the most suitable mode of administration depends in each individual case on the nature and severity of the condition to be treated and on the nature of the compound of formula I used in each case. Coated formulations and coated slow-release formulations also belong within the framework of the invention. Preference is given to acid- and gastric juice-resistant formulations. Suitable coatings resistant to gastric juice comprise cellulose acetate phthalate, polyvinyl acetate phthalate, hydroxypropylmethylcellulose phthalate and anionic polymers of methacrylic acid and methyl methacrylate.

Suitable pharmaceutical preparations for oral administration may be in the form of separate units such as, for example, capsules, cachets, suckable tablets or tablets, each of which contain a defined amount of the compound of formula I; as powders or granules, as solution or suspension in an aqueous or nonaqueous liquid; or as an oil-in-water or water-in-oil emulsion. These compositions may, as already mentioned, be prepared by any suitable pharmaceutical method which includes a step in which the active ingredient and the carrier (which may consist of one or more additional ingredients) are brought into contact. The compositions are generally produced by uniform and homogeneous mixing of the active ingredient with a liquid and/or finely divided solid carrier, after which the product is shaped if necessary. Thus, for example, a tablet can be produced by compressing or

molding a powder or granules of the compound, where appropriate with one or more additional ingredients. Compressed tablets can be produced by tableting the compound in free-flowing form such as, for example, a powder or granules, where appropriate mixed with a binder, glidant, inert diluent and/or one (or more) surface-active/dispersing agent(s) in a suitable machine. Molded tablets can be produced by molding the compound, which is in powder form and is moistened with an inert liquid diluent, in a suitable machine.

Pharmaceutical compositions which are suitable for peroral (sublingual) administration comprise suckable tablets which contain a compound of formula I with a flavoring, normally sucrose and gum arabic or tragacanth, and pastilles which comprise the compound in an inert base such as gelatin and glycerol or sucrose and gum arabic.

Pharmaceutical compositions suitable for parenteral administration comprise preferably sterile aqueous preparations of a compound of formula I, which are preferably isotonic with the blood of the intended recipient. These preparations are preferably administered intravenously, although administration may also take place by subcutaneous, intramuscular or intradermal injection. These preparations can preferably be produced by mixing the compound with water and making the resulting solution sterile and isotonic with blood. Injectable compositions of the invention generally contain from 0.1 to 5% by weight of the active compound.

Pharmaceutical compositions suitable for rectal administration are preferably in the form of single-dose suppositories. These can be produced by mixing a compound of the formula I with one or more conventional solid carriers, for example cocoa butter, and shaping the resulting mixture.

Pharmaceutical compositions suitable for topical use on the skin are preferably in the form of ointment, cream, lotion, paste, spray, aerosol or oil. Carriers which can be used are petrolatum, lanolin, polyethylene glycols, alcohols and combinations of two or more of these substances. The active ingredient is generally present in a concentration of from 0.1 to 15% by weight of the composition, for example from 0.5 to 2%.

Transdermal administration is also possible. Pharmaceutical compositions suitable for transdermal uses can be in the form of single plasters which are suitable for long-term close contact with the patient's epidermis. Such plasters suitably contain the active ingredient in an aqueous solution which is buffered where appropriate, dissolved and/or dispersed in an adhesive or dispersed in a polymer. A suitable active ingredient concentration is about 1% to 35%, preferably about 3% to 15%. A particular possibility is for the active ingredient to be released by electrotransport or iontophoresis as described, for example, in *Pharmaceutical Research*, 2(6): 318 (1986).

The compounds of the formula I are distinguished by favorable effects on metabolic disorders. They beneficially influence lipid and sugar metabolism, in particular they lower the triglyceride level and are suitable for the prevention and treatment of type II diabetes and arteriosclerosis and the diverse sequelae thereof.

### **Combinations with other medicaments**

The compounds of the invention can be administered alone or in combination with one or more further pharmacologically active substances which have, for example, favorable effects on metabolic disturbances or disorders frequently associated therewith. Examples of such medicaments are

1. medicaments which lower blood glucose, antidiabetics,
2. active ingredients for the treatment of dyslipidemias,
3. antiatherosclerotic medicaments,
4. antiobesity agents,
5. antiinflammatory active ingredients
6. active ingredients for the treatment of malignant tumors
7. antithrombotic active ingredients
8. active ingredients for the treatment of high blood pressure
9. active ingredients for the treatment of heart failure and
10. active ingredients for the treatment and/or prevention of complications caused by diabetes or associated with diabetes.

They can be combined with the compounds of the invention of the formula I in particular for a synergistic improvement in the effect. Administration of the active ingredient combination can take place either by separate administration of the active ingredients to the patient or in the form of combination products in which a plurality of active ingredients are present in one pharmaceutical preparation.

Examples which may be mentioned are:

#### Antidiabetics

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Suitable antidiabetics are disclosed for example in the Rote Liste 2001, chapter 12 or in the USP Dictionary of USAN and International Drug Names, US Pharmacopeia, Rockville 2001. Antidiabetics include all insulins and insulin derivatives such as, for example, Lantus® (see [www.lantus.com](http://www.lantus.com)) or Apidra®, and other fast-acting insulins (see US 6,221,633), GLP-1 receptor modulators as described in WO 01/04146 or else, for example, those disclosed in WO 98/08871 of Novo Nordisk A/S.

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The orally effective hypoglycemic active ingredients include, preferably, sulfonylureas, biguanides, meglitinides, oxadiazolidinediones, thiazolidinediones, glucosidase inhibitors, glucagon antagonists, GLP-1 agonists, DPP-IV inhibitors, potassium channel openers such as, for example, those disclosed in WO 97/26265 and WO 99/03861, insulin sensitizers, inhibitors of liver enzymes involved in the stimulation of gluconeogenesis and/or glycogenolysis, modulators of glucose uptake, compounds which alter lipid metabolism and lead to a change in the blood lipid composition, compounds which reduce food intake, PPAR and PXR modulators and active ingredients which act on the ATP-dependent potassium channel of the beta cells.

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In one embodiment of the invention, the compounds of the formula I are administered in combination with insulin.

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In one embodiment of the invention, the compounds of the formula I are administered in combination with substances which influence hepatic glucose

production such as, for example, glycogen phosphorylase inhibitors (see: WO 01/94300, WO 02/096864, WO 03/084923, WO 03/084922, WO 03/104188)

In one embodiment, the compounds of the formula I are administered in  
5 combination with a sulfonylurea such as, for example, tolbutamide, glibenclamide, glipizide or glimepiride.

In one embodiment, the compounds of the formula I are administered in combination with an active ingredient which acts on the ATP-dependent potassium  
10 channel of the beta cells, such as, for example, tolbutamide, glibenclamide, glipizide, glimepiride or repaglinide.

In one embodiment, the compounds of the formula I are administered in combination with a biguanide such as, for example, metformin.

15 In a further embodiment, the compounds of the formula I are administered in combination with a meglitinide such as, for example, repaglinide.

In one embodiment, the compounds of the formula I are administered in combination with a thiazolidinedione such as, for example, ciglitazone,  
20 pioglitazone, rosiglitazone or the compounds disclosed in WO 97/41097 of Dr. Reddy's Research Foundation, in particular 5-[[4-[(3,4-dihydro-3-methyl-4-oxo-2-quinazolinylmethoxy)phenyl]methyl]-2,4-thiazolidinedione.

In one embodiment, the compounds of the formula I are administered in  
25 combination with a DPPIV inhibitor as described, for example, in WO98/19998, WO99/61431, WO99/67278, WO99/67279, WO01/72290, WO 02/38541, WO03/040174, in particular P 93/01 (1-cyclopentyl-3-methyl-1-oxo-2-pentan ammonium chloride), P-31/98, LAF237 (1-[2-[3-hydroxyadamant-1-ylamino)acetyl]pyrrolidine-2-(S)-carbonitrile), TS021 ((2S, 4S)-4-fluoro-1-[[[(2-  
30 hydroxy-1,1-dimethylethyl)amino]-acetyl]pyrrolidine-2-carbonitrile monobenzenesulfonate).

In one embodiment of the invention, the compounds of the formula I are administered in combination with a PPARgamma agonist such as, for example,



rosiglitazone, pioglitazone.

In one embodiment, the compounds of the formula I are administered in combination with compounds with an inhibitory effect on SGLT-1 and/or 2, as disclosed directly or indirectly for example in PCT/EP03/06841, PCT/EP03/13454 and PCT/EP03/13455.

In one embodiment, the compounds of the formula I are administered in combination with an  $\alpha$ -glucosidase inhibitor such as, for example, miglitol or acarbose.

In one embodiment, the compounds of the formula I are administered in combination with more than one of the aforementioned compounds, e.g. in combination with a sulfonylurea and metformin, a sulfonylurea and acarbose, repaglinide and metformin, insulin and a sulfonylurea, insulin and metformin, insulin and troglitazone, insulin and lovastatin, etc.

#### Lipid modulators

In one embodiment of the invention, the compounds of the formula I are administered in combination with an HMGCoA reductase inhibitor such as lovastatin, fluvastatin, pravastatin, simvastatin, ivastatin, itavastatin, atorvastatin, rosuvastatin.

In one embodiment of the invention, the compounds of the formula I are administered in combination with a bile acid reabsorption inhibitor (see, for example, US 6,245,744, US 6,221,897, US 6,277,831, EP 0683 773, EP 0683 774).

In one embodiment of the invention, the compounds of the formula I are administered in combination with a polymeric bile acid adsorbent such as, for example, cholestyramine, colestesevelam.

In one embodiment of the invention, the compounds of the formula I are

administered in combination with a cholesterol absorption inhibitor as described for example in WO 0250027, or ezetimibe, tiqueside, pamaqueside.

In one embodiment of the invention, the compounds of the formula I are  
 5 administered in combination with an LDL receptor inducer (see, for example, US 6,342,512).

In one embodiment, the compounds of the formula I are administered in combination with bulking agents, preferably insoluble bulking agents (see, for  
 10 example, carob/Caromax® (Zunft H J; et al., Carob pulp preparation for treatment of hypercholesterolemia, ADVANCES IN THERAPY (2001 Sep-Oct), 18(5), 230-6.) Caromax is a carob-containing product from Nutrinova, Nutrition Specialties & Food Ingredients GmbH, Industriepark Höchst, 65926 Frankfurt/Main)).  
 Combination with Caromax® is possible in one preparation or by separate  
 15 administration of compounds of the formula I and Caromax®. Caromax® can in this connection also be administered in the form of food products such as, for example, in bakery products or muesli bars.

In one embodiment of the invention, the compounds of the formula I are  
 20 administered in combination with a PPARalpha agonist.

In one embodiment of the invention, the compounds of the formula I are administered in combination with a mixed PPAR alpha/gamma agonist such as, for example, AZ 242 (Tesaglitazar, (S)-3-(4-[2-(4-  
 25 methanesulfonyloxyphenyl)ethoxy]phenyl)-2-ethoxypropionic acid), BMS 298585 (N-[(4-methoxyphenoxy)carbonyl]-N-[[4-[2-(5-methyl-2-phenyl-4-oxazolyl)ethoxy]phenyl]methyl]glycine) or as described in WO 99/62872, WO 99/62871, WO 01/40171, WO 01/40169, WO96/38428, WO 01/81327, WO 01/21602, WO 03/020269, WO 00/64888 or WO 00/64876.

30 In one embodiment of the invention, the compounds of the formula I are administered in combination with a fibrate such as, for example, fenofibrate, gemfibrozil, clofibrate, bezafibrate.

In one embodiment of the invention, the compounds of the formula I are administered in combination with nicotinic acid or niacin.

5 In one embodiment of the invention, the compounds of the formula I are administered in combination with a CETP inhibitor, e.g. CP- 529, 414 (torcetrapib).

In one embodiment of the invention, the compounds of the formula I are administered in combination with an ACAT inhibitor.

10 In one embodiment of the invention, the compounds of the formula I are administered in combination with an MTP inhibitor such as, for example, implitapide.

15 In one embodiment of the invention, the compounds of the formula I are administered in combination with an antioxidant.

In one embodiment of the invention, the compounds of the formula I are administered in combination with a lipoprotein lipase inhibitor.

20 In one embodiment of the invention, the compounds of the formula I are administered in combination with an ATP citrate lyase inhibitor.

In one embodiment of the invention, the compounds of the formula I are administered in combination with a squalene synthetase inhibitor.

25 In one embodiment of the invention, the compounds of the formula I are administered in combination with a lipoprotein(a) antagonist.

#### Antiobesity agents

30 In one embodiment of the invention, the compounds of the formula I are administered in combination with a lipase inhibitor such as, for example, orlistat.

In one embodiment, the further active ingredient is fenfluramine or

dexfenfluramine.

In another embodiment, the further active ingredient is sibutramine.

- 5 In a further embodiment, the compounds of the formula I are administered in combination with CART modulators (see "Cocaine-amphetamine-regulated transcript influences energy metabolism, anxiety and gastric emptying in mice" Asakawa, A, et al., M.: Hormone and Metabolic Research (2001), 33(9), 554-558), NPY antagonists, e.g. naphthalene-1-sulfonic acid {4-[(4-aminoquinazolin-2-
- 10 ylamino)methyl]- cyclohexylmethyl}amide hydrochloride (CGP 71683A)), MC4 agonists (e.g. 1-amino-1,2,3,4-tetrahydronaphthalene-2-carboxylic acid [2-(3a-benzyl-2-methyl-3-oxo-2,3,3a,4,6,7-hexahydropyrazolo[4,3-c]pyridin-5-yl)-1-(4-chlorophenyl)-2-oxoethyl]-amide; (WO 01/91752)), orexin antagonists (e.g. 1-(2-methylbenzoxazol-6-yl)-3-[1,5]naphthyridin-4-ylurea hydrochloride (SB-334867-
- 15 A)), H3 agonists (3-cyclohexyl-1-(4,4-dimethyl-1,4,6,7-tetrahydroimidazo[4,5-c]pyridin-5-yl)propan-1-one oxalic acid salt (WO 00/63208)); TNF agonists, CRF antagonists (e.g. [2-methyl-9-(2,4,6-trimethylphenyl)-9H-1,3,9-triazafluoren-4-yl]dipropylamine (WO 00/66585)), CRF BP antagonists (e.g. urocortin), urocortin agonists,  $\beta$ 3 agonists (e.g. 1-(4-chloro-3-methanesulfonylmethylphenyl)-2-[2-(2,3-
- 20 dimethyl-1H-indol-6-yloxy)ethylamino]-ethanol hydrochloride (WO 01/83451)), MSH (melanocyte-stimulating hormone) agonists, CCK-A agonists (e.g. {2-[4-(4-chloro-2,5-dimethoxyphenyl)-5-(2-cyclohexylethyl)thiazol-2-ylcarbamoyl]-5,7-dimethylindol-1-yl}acetic acid trifluoroacetic acid salt (WO 99/15525)), serotonin reuptake inhibitors (e.g. dexfenfluramine), mixed serotonergic and noradrenergic
- 25 compounds (e.g. WO 00/71549), 5HT agonists e.g. 1-(3-ethylbenzofuran-7-yl)piperazine oxalic acid salt (WO 01/09111), bombesin agonists, galanin antagonists, growth hormone (e.g. human growth hormone), growth hormone-releasing compounds (6-benzyloxy-1-(2-diisopropylaminoethylcarbamoyl)-3,4-dihydro-1H-isoquinoline-2-carboxylic acid tertiary butyl ester (WO 01/85695)), TRH
- 30 agonists (see, for example, EP 0 462 884), uncoupling protein 2 or 3 modulators, leptin agonists (see, for example, Lee, Daniel W.; Leinung, Matthew C.; Rozhavskaya-Arena, Marina; Grasso, Patricia. Leptin agonists as a potential approach to the treatment of obesity. Drugs of the Future (2001), 26(9), 873-881), DA agonists (bromocriptine, Doprexin), lipase/amylase inhibitors (e.g. WO

00/40569), PPAR modulators (e.g. WO 00/78312), RXR modulators or TR- $\beta$  agonists.

In one embodiment of the invention, the further active ingredient is leptin.

5

In one embodiment, the further active ingredient is dexamphetamine, amphetamine, mazindole or phentermine.

In one embodiment, the compounds of the formula I are administered in  
10 combination with medicaments having effects on the coronary circulation and the vascular system, such as, for example, ACE inhibitors (e.g. ramipril), medicaments which act on the angiotensin-renaline system, calcium antagonists, beta blockers etc.

15 In one embodiment, the compounds of the formula I are administered in combination with medicaments having an antiinflammatory effect.

In one embodiment, the compounds of the formula I are administered in  
20 combination with medicaments which are employed for cancer therapy and cancer prevention.

It will be appreciated that every suitable combination of the compounds of the  
invention with one or more of the aforementioned compounds and optionally one  
or more other pharmacologically active substances is regarded as falling within the  
25 protection conferred by the present invention.

The activity of the compounds was tested as follows:

### 30 **Determination of EC<sub>50</sub> values of PPAR agonists in the cellular PPAR $\alpha$ assay**

#### Principle

The potency of substances which bind to human PPAR $\alpha$  and activate in an

agonistic manner is analyzed using a stably transfected HEK cell line (HEK= human embryo kidney) which is referred to here as PPARalpha reporter cell line. It contains two genetic elements, a luciferase reporter element (pdeltaM-GAL4-Luc-Zeo) and a PPARalpha fusion protein (GR-GAL4-humanPPARalpha-LBD) which

5 mediates expression of the luciferase reporter element depending on a PPARalpha ligand. The stably and constitutively expressed fusion protein GR-GAL4-humanPPARalpha-LBD binds in the cell nucleus of the PPARalpha reporter cell line via the GAL4 protein portion to the GAL4 DNA binding motifs 5'-upstream of the luciferase reporter element which is integrated in the genome of the cell line.

10 There is only little expression of the luciferase reporter gene without addition of a PPARalpha ligand if fatty acid-depleted fetal calf serum (cs-FCS) is used in the assay. PPARalpha ligands bind and activate the PPARalpha fusion protein and thereby bring about expression of the luciferase reporter gene. The luciferase which is formed can be detected by means of chemiluminescence via an

15 appropriate substrate.

#### Construction of the cell line

The PPARalpha reporter cell line was prepared in 2 stages. Firstly, the luciferase

20 reporter element was constructed and stably transfected into HEK cells. For this purpose, five binding sites of the yeast transcription factor GAL4 (each 5'-CGGAGTACTGTCCTCCGAG-3') (SEQ ID No. 1) were cloned in 5'-upstream of a 68 bp-long minimal MMTV promoter (Genbank Accession # V01175). The minimal MMTV promoter section contains a CCAAT box and a TATA element in order to

25 enable efficient transcription by RNA polymerase II. The cloning and sequencing of the GAL4-MMTV construct took place in analogy to the description of Sambrook J. *et. al.* (Molecular cloning, Cold Spring Harbor Laboratory Press, 1989). Then the complete *Photinus pyralis* gene (Genbank Accession # M15077) was cloned in 3'-downstream of the GAL4-MMTV element. After sequencing, the luciferase

30 reporter element consisting of five GAL4 binding sites, MMTV promoter and luciferase gene was recloned into a plasmid which confers zeocin resistance in order to obtain the plasmid pdeltaM-GAL4-Luc-Zeo. This vector was transfected into HEK cells in accordance with the statements in Ausubel, F.M. *et al.* (Current protocols in molecular biology, Vol. 1-3, John Wiley & Sons, Inc., 1995). Then

zeocin-containing medium (0.5 mg/ml) was used to select a suitable stable cell clone which showed very low basal expression of the luciferase gene.

In a second step, the PPARalpha fusion protein (GR-GAL4-humanPPARalpha-LBD) was introduced into the stable cell clone described. For this purpose, initially

5 the cDNA coding for the N-terminal 76 amino acids of the glucocorticoid receptor (Genbank Accession # P04150) was linked to the cDNA section coding for amino acids 1-147 of the yeast transcription factor GAL4 (Genbank Accession # P04386). The cDNA of the ligand-binding domain of the human PPARalpha receptor (amino acids S167-Y468; Genbank Accession # S74349) was cloned in at the 3'-end of  
10 this GR-GAL4 construct. The fusion construct prepared in this way (GR-GAL4-humanPPARalpha-LBD) was recloned into the plasmid pcDNA3 (from Invitrogen) in order to enable constitutive expression therein by the cytomegalovirus promoter. This plasmid was linearized with a restriction endonuclease and stably transfected into the previously described cell clone containing the luciferase reporter element.  
15 The finished PPARalpha reporter cell line which contains a luciferase reporter element and constitutively expresses the PPARalpha fusion protein (GR-GAL4-human PPARalpha-LBD) was isolated by selection with zeocin (0.5 mg/ml) and G418 (0.5 mg/ml).

## 20 Assay procedure

The activity of PPARalpha agonists is determined in a 3-day assay which is described below:

### 25 Day 1

The PPARalpha reporter cell line is cultivated to 80% confluence in DMEM (# 41965-039, Invitrogen) which is mixed with the following additions: 10% cs-FCS (fetal calf serum; #SH-30068.03, Hyclone), 0.5 mg/ml zeocin (#R250-01, Invitrogen), 0.5 mg/ml G418 (#10131-027, Invitrogen), 1% penicillin-streptomycin  
30 solution (#15140-122, Invitrogen) and 2 mM L-glutamine (#25030-024, Invitrogen). The cultivation takes place in standard cell culture bottles (# 353112, Becton Dickinson) in a cell culture incubator at 37°C in the presence of 5% CO<sub>2</sub>. The 80%-confluent cells are washed once with 15 ml of PBS (#14190-094, Invitrogen), treated with 3 ml of trypsin solution (#25300-054, Invitrogen) at 37°C for 2 min,

taken up in 5 ml of the DMEM described and counted in a cell counter. After dilution to 500.000 cells/ml, 35,000 cells are seeded in each well of a 96 well microtiter plate with a clear plastic base (#3610, Corning Costar). The plates are incubated in the cell culture incubator at 37°C and 5% CO<sub>2</sub> for 24 h.

5

### Day 2

PPARalpha agonists to be tested are dissolved in DMSO in a concentration of 10 mM. This stock solution is diluted in DMEM (#41965-039, Invitrogen) which is mixed with 5% cs-FCS (#SH-30068.03, Hyclone), 2 mM L-glutamine (#25030-024, Invitrogen) and the previously described antibiotics (zeocin, G418, penicillin and streptomycin).

Test substances are tested in 11 different concentrations in the range from 10 µM to 100 pM. More potent compounds are tested in concentration ranges from 1 µM to 10 pM or between 100 nM and 1 pM.

15 The medium of the PPARalpha reporter cell line seeded on day 1 is completely removed by aspiration, and the test substances diluted in medium are immediately added to the cells. The dilution and addition of the substances is carried out by a robot (Beckman FX). The final volume of the test substances diluted in medium is 100 µl per well of a 96 well microtiter plate. The DMSO concentration in the assay

20 is less than 0.1 % v/v in order to avoid cytotoxic effects of the solvent.

Each plate was charged with a standard PPARalpha agonist, which was likewise diluted in 11 different concentrations, in order to demonstrate the functioning of the assay in each individual plate. The assay plates are incubated in an incubator at 37°C and 5% CO<sub>2</sub> for 24 h.

25

### Day 3

The PPARalpha reporter cells treated with the test substances are removed from the incubator, and the medium is aspirated off. The cells are lysed by pipetting 50 µl of Bright Glo reagent (from Promega) into each well of a 96 well microtiter plate.

30 After incubation at room temperature in the dark for 10 minutes, the microtiter plates are measured in the luminometer (Trilux from Wallac). The measuring time for each well of a microtiter plate is 1 sec.

### Evaluation



The raw data from the luminometer are transferred into a Microsoft Excel file. Dose-effect plots and EC50 values of PPAR agonists are calculated using the XL.Fit program as specified by the manufacturer (IDBS).

5

The PPARalpha EC50 values for the compounds of Examples 1 to ... in this assay are in the range from 0.4nM to >10 µM.

10 The results for the activity of some compounds of the invention of the formula I are indicated in Table I below:

Table I

Example No.	EC50 PPARalpha [nM]
1	1.1
2	1.0
3	0.56
5	0.38
9	8.8
10	74
11	28

15 It is evident from Table I that the compounds of the invention of the formula I activate the PPARalpha receptor and thus bring about for example in analogy to fibrates in clinical use a lowering of triglycerides in the body (see, for example, J.-Ch. Fruchard et al.: PPARS, Metabolic Disease and Atherosclerosis, Pharmacological Research, Vol. 44, No. 5, 345-52, 2001; S. Kersten et al.: Roles of PPARs in health and disease, NATURE, VOL 405, 25 MAY 2000, 421-4; I. Pineda et al.: Peroxisome proliferator-activated receptors: from transcriptional

20

control to clinical practice, Curr Opin Lipidol 12: 2001, 245-254).

### **Determination of EC50 values of PPAR agonists in the cellular PPARgamma assay**

5

#### **Principle**

10 A transient transfection system is employed to determine the cellular PPARgamma activity of PPAR agonists. It is based on the use of a luciferase reporter plasmid (pGL3basic-5xGAL4-TK) and of a PPARgamma expression plasmid (pcDNA3-GAL4-humanPPARgammaLBD). Both plasmids are transiently transfected into human embryonic kidney cells (HEK cells). There is then expression in these cells of the fusion protein GAL4-humanPPARgammaLBD which binds to the GAL4  
15 binding sites of the reporter plasmid. In the presence of a PPARgamma-active ligand, the activated fusion protein GAL4-humanPPARgammaLBD induces expression of the luciferase reporter gene, which can be detected in the form of a chemiluminescence signal after addition of a luciferase substrate. As a difference from the stably transfected PPARalpha reporter cell line, in the cellular  
20 PPARgamma assay the two components (luciferase reporter plasmid and PPARgamma expression plasmid) are transiently transfected into HEK cells because stable and permanent expression of the PPARgamma fusion protein is cytotoxic.

#### **25 Construction of the plasmids**

The luciferase reporter plasmid pGL3basic-5xGAL4-TK is based on the vector pGL3basic from Promega. The reporter plasmid is prepared by cloning five binding sites of the yeast transcription factor GAL4 (each binding site with the sequence  
30 5'-CTCGGAGGACAGTACTCCG-3') (SEQ ID No. 2), together with a 160 bp-long thymidine kinase promoter section (Genbank Accession # AF027128) 5'-upstream into pGL3basic. 3'-downstream of the thymidine kinase promoter is the complete luciferase gene from Photinus pyralis (Genbank Accession # M15077) which is already a constituent of the plasmid pGL3basic used. The cloning and sequencing

of the reporter plasmid pGL3basic-5xGAL4-TK took place in analogy to the description in Sambrook J. *et. al.* (Molecular cloning, Cold Spring Harbor Laboratory Press, 1989).

The PPARgamma expression plasmid pcDNA3-GAL4-humanPPARgammaLBD was prepared by first cloning the cDNA coding for amino acids 1-147 of the yeast transcription factor GAL4 (Genbank Accession # P04386) into the plasmid pcDNA3 (from Invitrogen) 3'-downstream of the cytomegalovirus promoter. Subsequently, the cDNA of the ligand-binding domain (LBD) of the human PPARgamma receptor (amino acids 1152-Y475; Accession # g1480099) 3'-downstream of the GAL4 DNA binding domain. Cloning and sequencing of the PPARgamma expression plasmid pcDNA3-GAL4-humanPPARgammaLBD again took place in analogy to the description in Sambrook J. *et. al.* (Molecular cloning, Cold Spring Harbor Laboratory Press, 1989). Besides the luciferase reporter plasmid pGL3basic-5xGAL4-TK and the PPARgamma expression plasmid pcDNA3-GAL4-humanPPARgammaLBD, also used for the cellular PPARgamma assay are the reference plasmid pRL-CMV (from Promega) and the plasmid pBluescript SK(+) from Stratagene. All four plasmids were prepared using a plasmid preparation kit from Qiagen, which ensured a plasmid quality with a minimal endotoxin content, before transfection into HEK cells.

#### Assay procedure

The activity of PPARgamma agonists is determined in a 4-day assay which is described below. Before the transfection, HEK cells are cultivated in DMEM (# 41965-039, Invitrogen) which is mixed with the following additions: 10% FCS (#16000-044, Invitrogen), 1% penicillin-streptomycin solution (#15140-122, Invitrogen) and 2 mM L-glutamine (#25030-024, Invitrogen).

#### Day 1

Firstly, solution A, a transfection mixture which contains all four plasmids previously described in addition to DMEM, is prepared. The following amounts are used to make up 3 ml of solution A for each 96 well microtiter plate for an assay: 2622 µl of antibiotic- and serum-free DMEM (# 41965-039, Invitrogen), 100 µl of reference plasmid pRL-CMV (1 ng/µl), 100 µl of luciferase reporter plasmid

pGL3basic-5xGAL4-TK (10 ng/μl), 100 μl of PPARgamma expression plasmid pcDNA3-GAL4-humanPPARgammaLBD (100 ng/μl) and 78 μl of plasmid pBluescript SK(+) (500 ng/μl). Then 2 ml of solution B are prepared by mixing 1.9 ml of DMEM (# 41965-039, Invitrogen) with 100 μl of PolyFect transfection reagent (from Qiagen) for each 96 well microtiter plate. Subsequently, 3 ml of solution A are mixed with 2 ml of solution B to give 5 ml of solution C, which is thoroughly mixed by multiple pipetting and incubated at room temperature for 10 min.

80%-confluent HEK cells from a cell culture bottle with a capacity of 175 cm<sup>2</sup> are washed once with 15 ml of PBS (#14190-094, Invitrogen) and treated with 3 ml of trypsin solution (#25300-054, Invitrogen) at 37°C for 2 min. The cells are then taken up in 15 ml of DMEM (# 41965-039, Invitrogen) which is mixed with 10% FCS (# 16000-044, Invitrogen), 1% penicillin-streptomycin solution (#15140-122, Invitrogen) and 2 mM L-glutamine (#25030-024, Invitrogen). After the cell suspension has been counted in a cell counter, the suspension is diluted to 250,000 cells/ml. 15 ml of this cell suspension are mixed with 5 ml of solution C for one microtiter plate. 200 μl of the suspension are seeded in each well of a 96 well microtiter plate with a clear plastic base (#3610, Corning Costar). The plates are incubated in a cell culture incubator at 37°C and 5% CO<sub>2</sub> for 24 h.

## Day 2

PPAR agonists to be tested are dissolved in DMSO in a concentration of 10 mM. This stock solution is diluted in DMEM (# 41965-039, Invitrogen) which is mixed with 2% Ultrosor (#12039-012, Biosepra), 1% penicillin-streptomycin solution (#15140-122, Invitrogen) and 2 mM L-glutamine (#25030-024, Invitrogen). Test substances are tested in a total of 11 different concentrations in the range from 10 μM to 100 pM. More potent compounds are tested in concentration ranges from 1 μM to 10 pM.

The medium of the HEK cells transfected and seeded on day 1 is completely removed by aspiration, and the test substances diluted in medium are immediately added to the cells. The dilution and addition of the substances is carried out by a robot (Beckman FX). The final volume of the test substances diluted in medium is 100 μl per well of a 96 well microtiter plate. Each plate is charged with a standard PPARgamma agonist, which is likewise diluted in 11 different concentrations, in order to demonstrate the functioning of the assay in each individual plate. The

assay plates are incubated in an incubator at 37°C and 5% CO<sub>2</sub>.

#### Day 4

After removal of the medium by aspiration, 50 µl of Dual-Glo™ reagent (Dual-Glo™ Luciferase Assay System; Promega) are added to each well in accordance with the manufacturer's instructions in order to lyse the cells and provide the substrate for the firefly luciferase (*Photinus pyralis*) formed in the cells. After incubation at room temperature in the dark for 10 minutes, the firefly luciferase-mediated chemiluminescence is measured in a measuring instrument (measuring time/well 1 sec; Trilux from Wallac). Then 50 µl of the Dual-Glo™ Stop & Glo reagent (Dual-Glo™ Luciferase Assay System; Promega) is added to each well in order to stop the activity of the firefly luciferase and provide the substrate for the Renilla luciferase expressed by the reference plasmid pRL-CMV. After incubation at room temperature in the dark for a further 10 minutes, a chemiluminescence mediated by the Renilla luciferase is again measured for 1 sec/well in the measuring instrument.

#### Evaluation

The crude data from the luminometer are transferred into a Microsoft Excel file. The firefly/Renilla luciferase activity ratio is determined for each measurement derived from one well of the microtiter plate. The dose-effect plots and EC50 values of PPAR agonists are calculated from the ratios by the XL.Fit program as specified by the manufacturer (IDBS).

PPARgamma EC50 values in the range from 160nM to >10 µM were measured for the PPAR agonists described in this application.

The citation of any reference herein should not be construed as an admission that such reference is available as "Prior Art" to the instant application.

The present invention is not to be limited in scope by the specific embodiments describe herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing

description and the accompanying figures. Such modifications are intended to fall within the scope of the appended claims.

Various publications are cited herein, the disclosures of which are incorporated by  
 5 reference in their entireties.

The examples given below serve to illustrate the invention, but without limiting it.

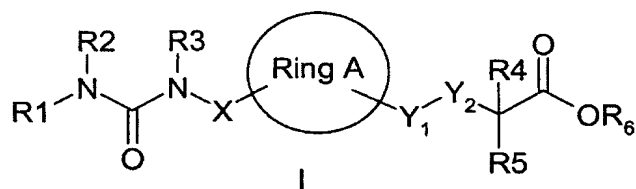
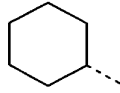
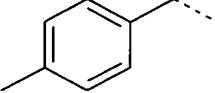
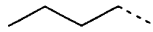
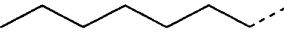
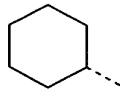
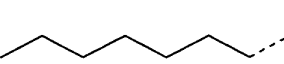
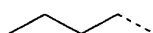
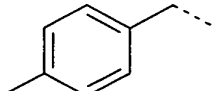
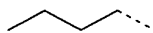
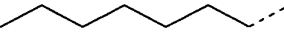
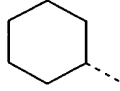

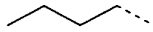
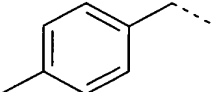
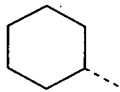
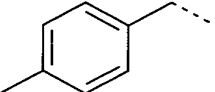
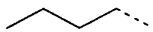
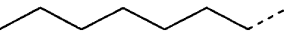

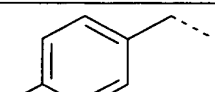
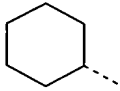
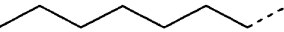
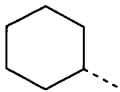
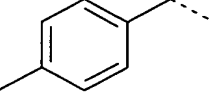
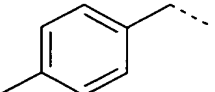
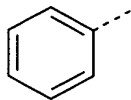
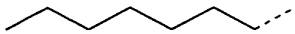
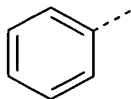
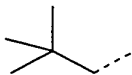


Table II:

In the examples below, R1 = H, X = CH<sub>2</sub>-CH<sub>2</sub>-O, R6 = H and ring A = cis-cyclohexane-1,3-diyl.

Ex.	R2 <sup>b</sup>	R3 <sup>b</sup>	Y1	Y2	-R4	-R5
1			—	(CH <sub>2</sub> ) <sub>2</sub>	-C <sub>2</sub> H <sub>5</sub>	-H
2			—	(CH <sub>2</sub> ) <sub>2</sub>	-C <sub>2</sub> H <sub>5</sub>	-H
3			—	(CH <sub>2</sub> ) <sub>2</sub>	-C <sub>2</sub> H <sub>5</sub>	-H
4			—	(CH <sub>2</sub> ) <sub>2</sub>	-C <sub>2</sub> H <sub>5</sub>	-H
5			—	(CH <sub>2</sub> ) <sub>2</sub>	-CH(CH <sub>3</sub> ) <sub>2</sub>	-H
6			—	(CH <sub>2</sub> ) <sub>2</sub>	-CH(CH <sub>3</sub> ) <sub>2</sub>	-H
7			—	(CH <sub>2</sub> ) <sub>2</sub>	-CH(CH <sub>3</sub> ) <sub>2</sub>	-H
8			—	(CH <sub>2</sub> ) <sub>2</sub>	-CH(CH <sub>3</sub> ) <sub>2</sub>	-H
9			—	(CH <sub>2</sub> ) <sub>2</sub>	-CH <sub>3</sub>	-CH <sub>3</sub>
10			—	(CH <sub>2</sub> ) <sub>2</sub>	-CH <sub>3</sub>	-CH <sub>3</sub>
11			—	(CH <sub>2</sub> ) <sub>2</sub>	-CH <sub>3</sub>	-CH <sub>3</sub>
12			—	(CH <sub>2</sub> ) <sub>2</sub>	-CH <sub>3</sub>	-CH <sub>3</sub>
13	H <sub>5</sub> C <sub>2</sub> —		CO	-NH—	-CH(CH <sub>3</sub> ) <sub>2</sub> <sup>a</sup>	-H

Ex.	R2 <sup>b</sup>	R3 <sup>b</sup>	Y1	Y2	-R4	-R5
14			CO	-NH-	-CH(CH <sub>3</sub> ) <sub>2</sub> <sup>a</sup>	-H
15			CO	-NH-	-CH(CH <sub>3</sub> ) <sub>2</sub> <sup>a</sup>	-H

a

In these examples, the stereocenter which carries the isopropyl group is S-configured.

b

The broken line indicates the point of attachment to the substituent.

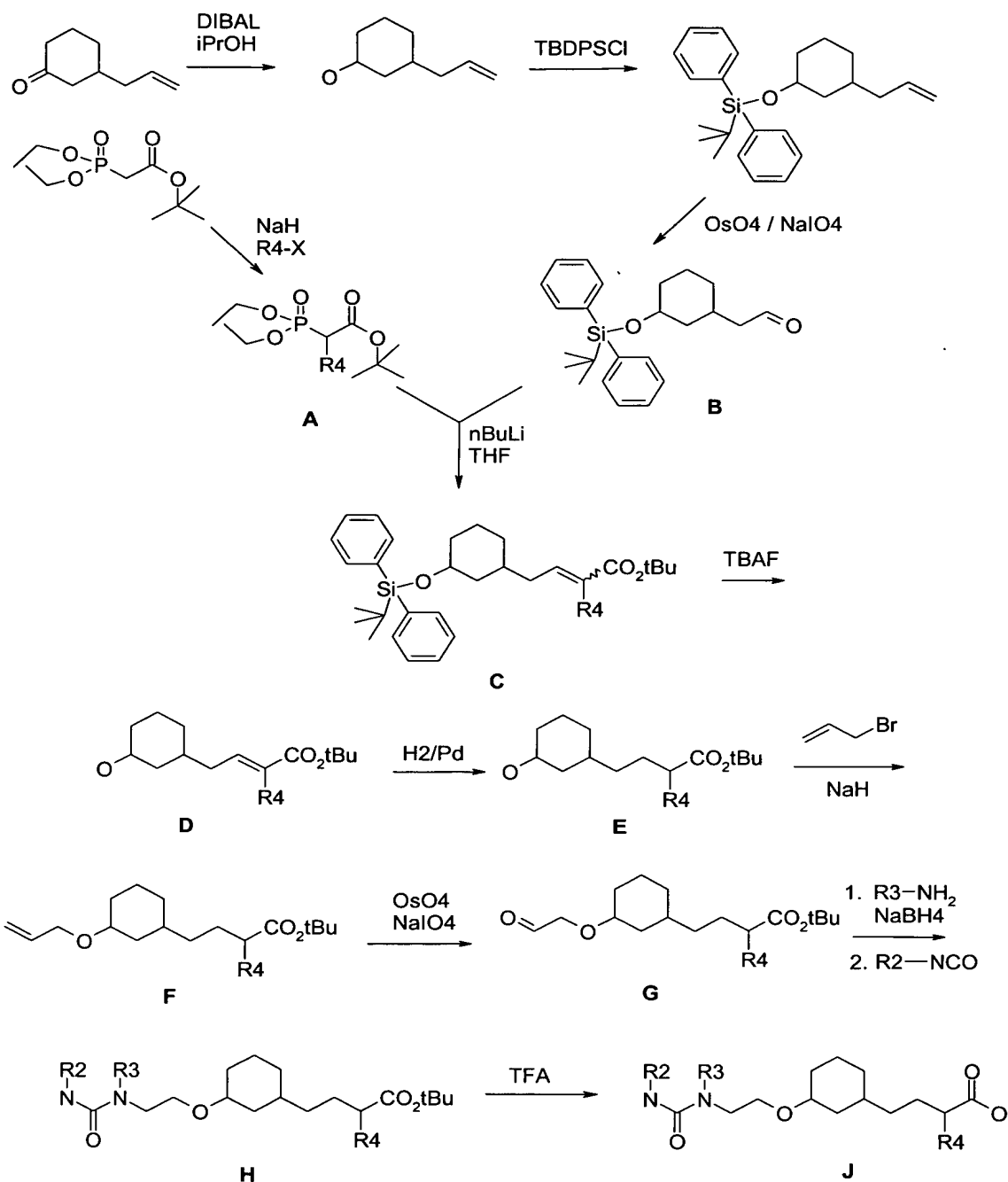
5

The invention furthermore provides processes for preparing the compounds of the formula I which are obtained in accordance with the reaction schemes A, B and C

10 below:



## Process A:



- 5 The compound of the general formula A in which R<sub>4</sub> is as defined above is deprotected with *n*-butyllithium in tetrahydrofuran at  $-78^{\circ}\text{C}$ , and compound B is then added at this temperature, giving a compound of the general formula C.

The compound C is then reacted with tetrabutylammonium fluoride solution in tetrahydrofuran to give compound D. The latter is hydrogenated with hydrogen

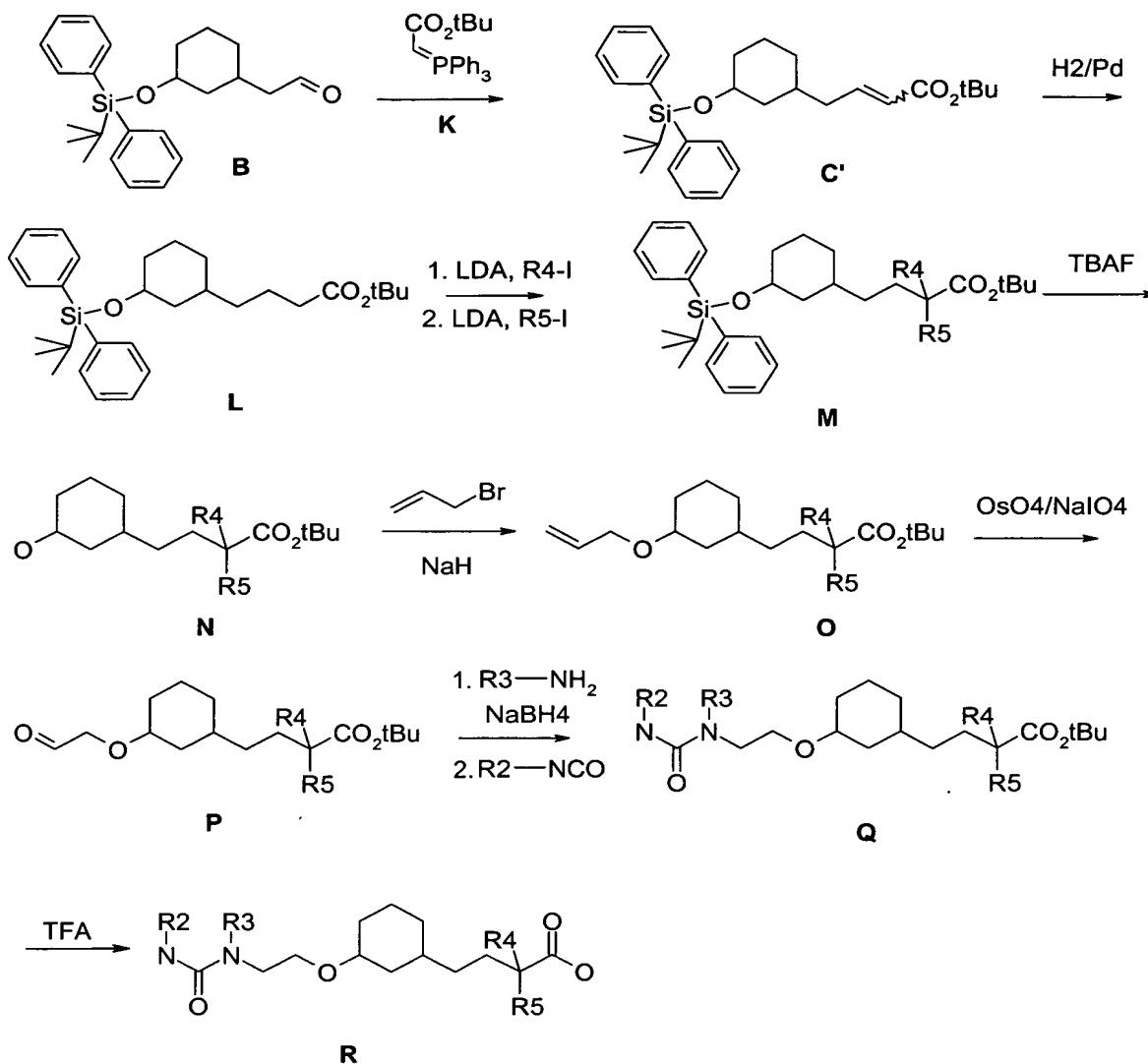
over palladium-on-carbon, giving compound E. Compound E is deprotonated with sodium hydride in dimethylformamide, allyl bromide is added and the mixture is stirred at room temperature for a number of hours, giving compound F. The latter is reacted with osmium tetroxide and sodium periodate in diethyl ether, giving  
5 aldehyde G.

Compound G is then stirred with a primary amine  $R_3-NH_2$ , where  $R_3$  is as defined above, and sodium borohydride in methanol at  $0^\circ C$ , worked up and then reacted in dimethylformamide with an isocyanate of the general formula  $R_2-NCO$ , where  $R_2$   
10 is as defined above, to give the compound of the general formula H.

To cleave the tert-butyl ester, compound H is stirred at room temperature in trifluoroacetic acid for a number of hours, giving the compound of the general  
15 formula J.

Using this process, it is possible to synthesize the compounds of Examples 1 to 8.

## Process B:



Compound B (see process A) is reacted with the compound of the general formula  
 5 K to give compound C' where  $\text{R}_4 = \text{H}$ . The latter compound is hydrogenated with hydrogen over palladium-on-carbon, giving compound L.

Compound L is deprotonated with lithium diisopropylamide in tetrahydrofuran at  $0^\circ\text{C}$  and then reacted with an alkyl iodide of the general formula  $\text{R}_4\text{-I}$ , where  $\text{R}_4$   
 10 may have the meaning described above. After work-up, this compound is then again deprotonated with lithium diisopropylamide in tetrahydrofuran at  $0^\circ\text{C}$  and subsequently reacted with an alkyl iodide of the general formula  $\text{R}_5\text{-I}$ , where  $\text{R}_5$  may have the meaning described above, giving the compound of the general formula M.

Compound M is reacted with tetrabutylammonium fluoride in tetrahydrofuran to give compound N which is deprotonated with sodium hydride in dimethylformamide and reacted with allyl bromide to give compound O. The latter is converted with osmium tetroxide and sodium periodate in diethyl ether to give compound P.

5

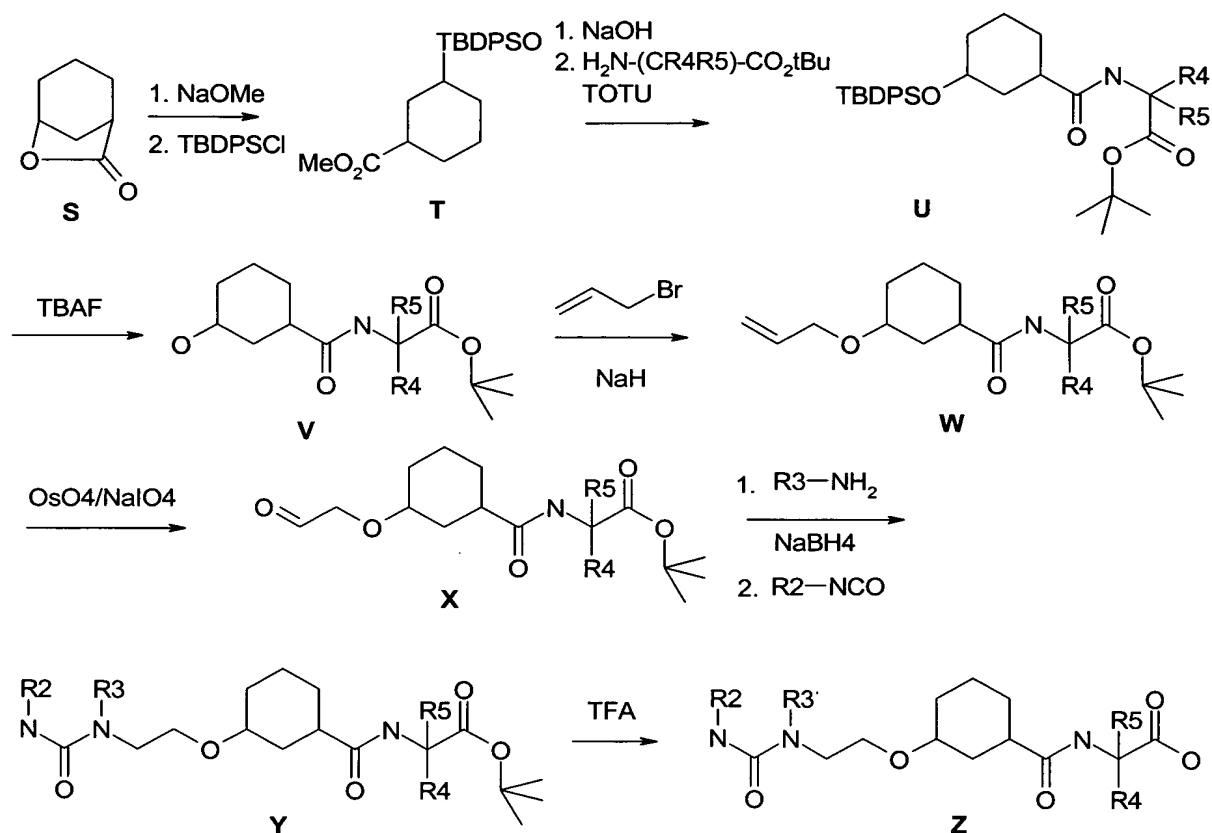
Compound P is then stirred with a primary amine of the general formula  $R_3-NH_2$ , where  $R_3$  is as defined above, and sodium borohydride in methanol at  $0^\circ C$ , worked up and then reacted in dimethylformamide with an isocyanate of the general formula  $R_2-NCO$ , where  $R_2$  is as defined above, giving the compound of the general formula Q.

10

To cleave the tert-butyl ester, compound Q is stirred in trifluoroacetic acid at room temperature for a number of hours, giving the compound of the general formula R.

15 Using this process, it is possible to synthesize the compounds of Examples 9 to 12.

## Process C:



- 5 Compound S is stirred at room temperature in methanol with sodium methoxide. After work-up, the product is converted with tert-butyldiphenylsilyl chloride and imidazole in dimethylformamide at room temperature into compound T.

Compound T is stirred in isopropanol with sodium hydroxide at 60°C for 1 hour.

- 10 After work-up, the product is reacted in dimethylformamide with a tert-butyl ester of an  $\alpha$ -amino acid, hydroxybenzotriazole, diisopropylethylamine and O-[cyano(ethoxycarbonyl)methyleneamino]-1,1,3,3,-tetramethyluronium tetrafluoroborate (TOTU), giving the product of the general formula U in which R<sub>4</sub> and R<sub>5</sub> are as defined above.

15

Compound U is reacted with tetrabutylammonium fluoride in tetrahydrofuran, giving compound V. The latter is deprotonated with sodium hydride in dimethylformamide and alkylated with allyl bromide, giving compound W. The

terminal double bond is then cleaved with osmium tetroxide and sodium periodate in diethyl ether, giving aldehyde X.

Compound X is reacted with a primary amine of the general formula  $R^3-NH_2$ , where  $R^2$  is as defined above, in methanol with sodium borohydride, worked up and then converted in dimethylformamide with an isocyanate of the general formula  $R^2-NCO$ , where  $R^2$  is as defined above, into compound Y. The latter is converted by stirring in trifluoroacetic acid into product Z.

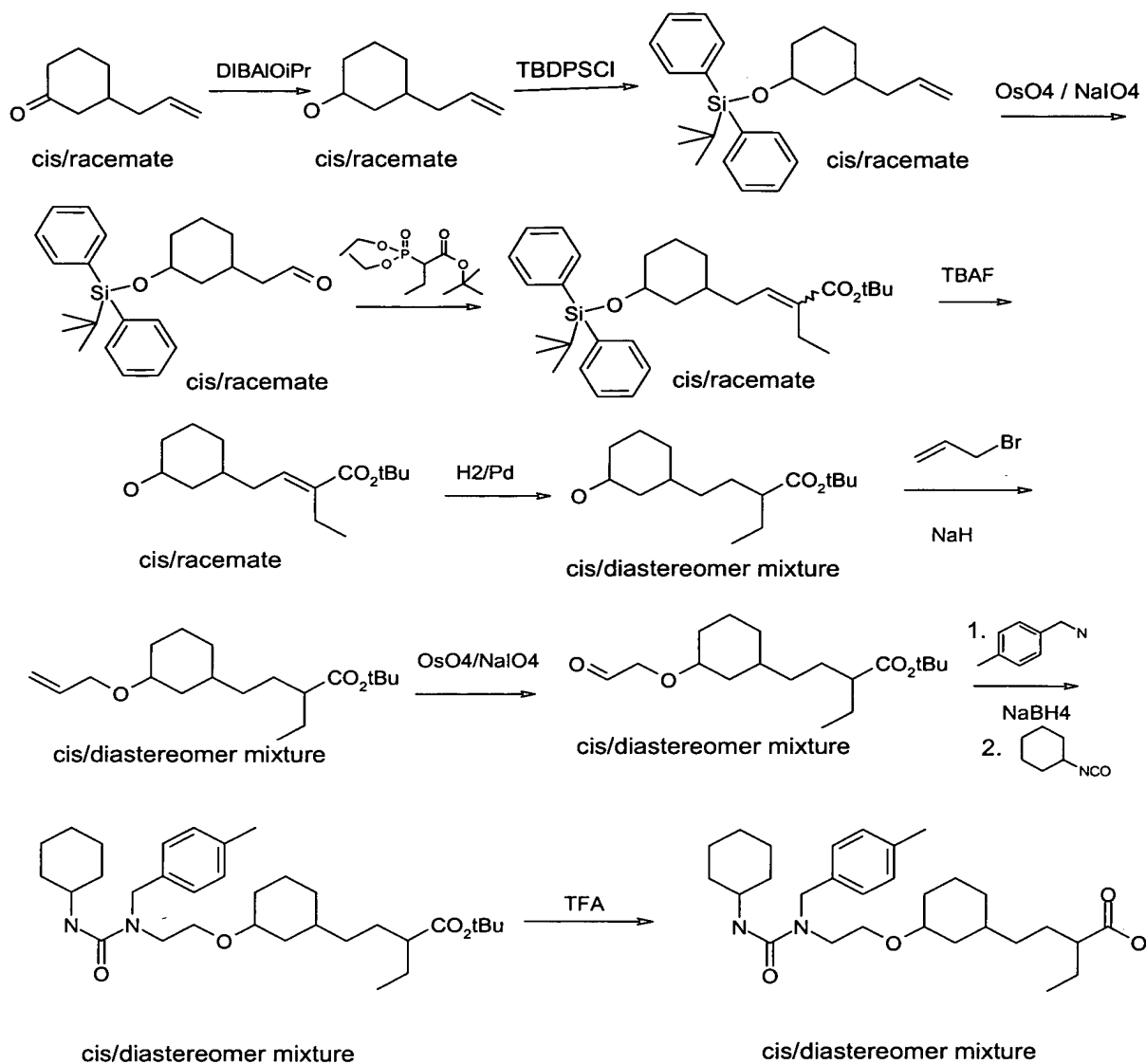
Using this process, it is possible to synthesize Examples 13 to 15.

Other compounds of the formula I can be prepared analogously or by known processes.

The syntheses of the example compounds are described below.

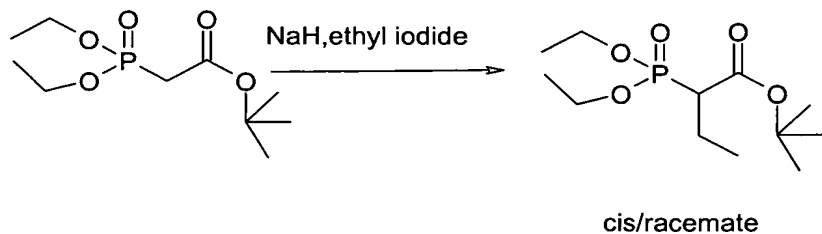
#### Example 1

4-[cis-3-{2-[3-Cyclohexyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)-2-ethylbutyric acid



### tert-Butyl 2-(diethoxyphosphoryl)butyrate

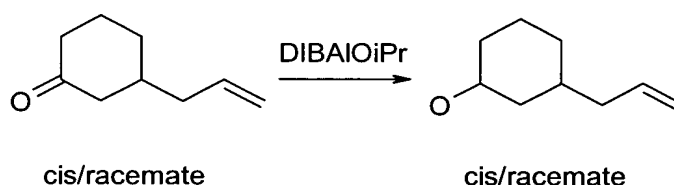
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9.3 ml of tert-butyl diethylphosphonoacetate are dissolved in 80 ml of dimethylformamide, and 1.38 g of sodium hydride (60% strength in paraffin oil) are

added a little at a time at 0°C. The suspension is stirred at 0°C for 15 minutes, and 4.02 ml of ethyl iodide are then added. The mixture is stirred at room temperature for 12 hours. 250 ml of ethyl acetate are then added, and the reaction mixture is washed three times with in each case 150 ml of water. The organic phase is dried over magnesium sulfate and concentrated under reduced pressure. The residue is purified on silica gel using the mobile phase n-heptane:ethyl acetate = 5:1. This gives 6.43 g of tert-butyl 2-(diethoxyphosphoryl)butyrate as an oil.  $C_{13}H_{27}O_5P$  (294.33),  $^1H$ -NMR ( $CDCl_3$ ,  $\delta$  = ppm): 4.15 (q, 4H), 2.73 (ddd, 1H), 2.0-1.8 (m, 2H), 1.49 (s, 9H), 1.35 (q, 6H), 1.00 (t, 3H).

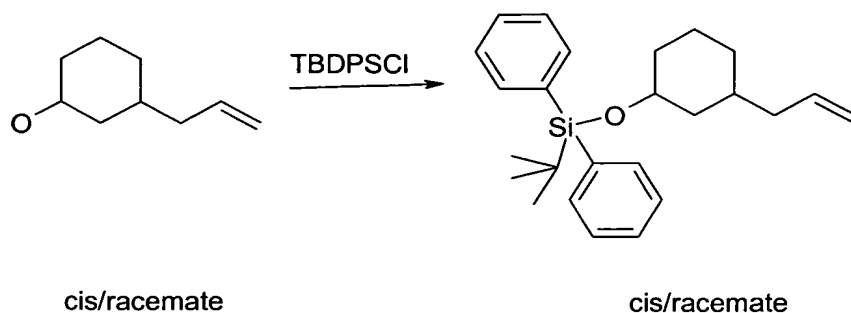
#### cis-3-Allylcyclohexanol



87 ml of a 1 molar solution of lithium diisobutylaluminum hydride in n-hexane are dissolved in 100 ml of diethyl ether, and 7 ml of isopropanol are added at 0°C. After the evolution of gas has ended, 12.4 g of 3-allylcyclohexanone, dissolved in 50 ml of diethyl ether, are added. The mixture is stirred at room temperature for 48 hours. The reaction mixture is quenched by addition of 1M hydrochloric acid and the aqueous phase is saturated with sodium chloride and extracted five times with in each case 200 ml of ethyl acetate. The combined organic phases are washed with 2N sodium hydroxide solution and dried over magnesium sulfate, and the solvent is then removed under reduced pressure. The residue is purified on silica gel using the mobile phase n-heptane:ethyl acetate = 15:1  $\Rightarrow$  5:1. This gives 6.8 g of cis-3-allylcyclohexanol as an oil.  $C_9H_{16}O$  (140.23), MS(ESI): 141 ( $M+H^+$ ),  $R_f$ (n-heptane:ethyl acetate = 2:1) = 0.22.

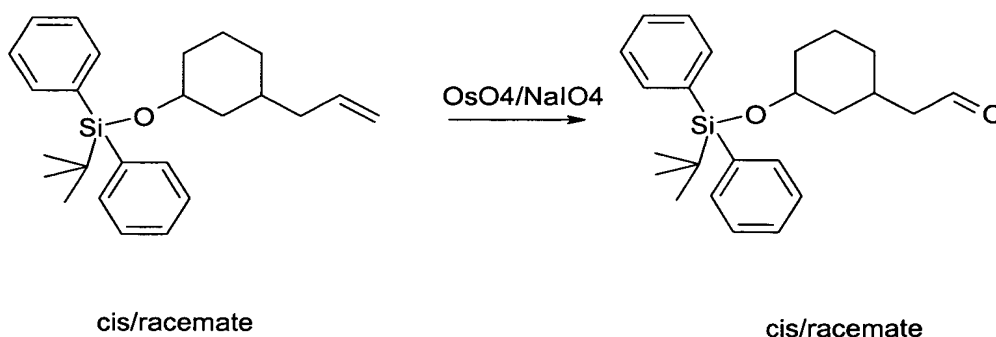
(cis-3-Allylcyclohexyloxy)-tert-butyl-diphenylsilane





- 6.8 g of cis-3-allylcyclohexanol and 15 ml of tert-butyldiphenylsilyl chloride, 5 g of imidazole and 200 mg of dimethylaminopyridine are dissolved in 100 ml of dimethylformamide and stirred at room temperature for 12 hours. 400 ml of methyl tert-buthyl ether are added to the reaction mixture, and the mixture is washed three times with water. The organic phase is dried over magnesium sulfate and the solvent is then removed under reduced pressure. This gives 20.5 g of (cis-3-allylcyclohexyloxy)tert-butyl-diphenylsilane as an oil.  $\text{C}_{25}\text{H}_{34}\text{OSi}$  (378.64),
- 10 MS(ESI): 379 ( $\text{M}+\text{H}^+$ ),  $R_f(\text{n-heptane:ethyl acetate} = 2:1) = 0.93$ .

[cis-3-(tert-Butyl-diphenylsilyloxy)cyclohexyl]acetaldehyde



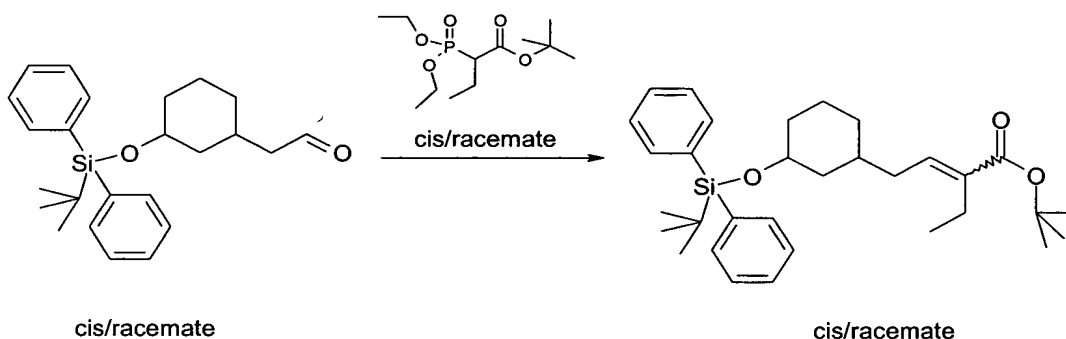
15

- 5.5 g of (cis-3-allylcyclohexyloxy)-tert-butyl-diphenylsilane are dissolved in 100 ml of diethyl ether, and 9.4 g of sodium periodate, dissolved in 100 ml of water, are added. At  $0^\circ\text{C}$ , 15 ml of an osmium tetroxide solution (2.5% by weight in tert-butanol) are added, and the mixture is stirred vigorously at room temperature.
- 20 After 5 hours, a further 5 g of sodium periodate are added, and the mixture is stirred at room temperature for another 3 hours. The reaction mixture is then diluted by addition of 300 ml of methyl tert-buthyl ether and washed with saturated

sodium thiosulfate solution. The organic phase is dried over magnesium sulfate and the solvent is then removed under reduced pressure. This gives 6 g of [cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]acetaldehyde as a yellow-brown oil.

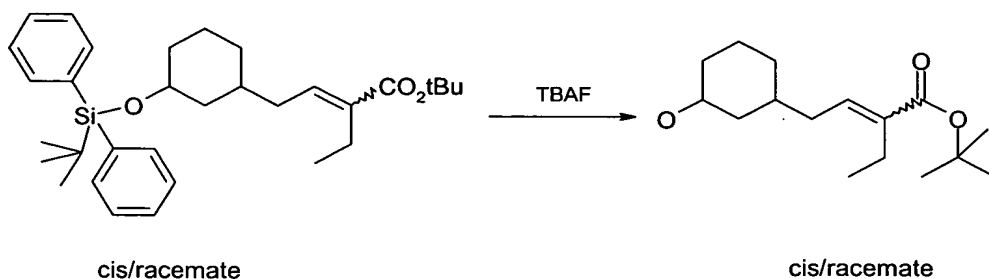
$C_{24}H_{32}O_2Si$  (380.61), MS(ESI): 381 ( $M+H^+$ ),  $R_f$ (n-heptane:ethyl acetate = 5:1) = 0.44.

tert-Butyl 4-[cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]-2-ethylbut-2-enoate



6.43 g of tert-butyl 2-(diethoxyphosphoryl)butyrate are dissolved in 90 ml of tetrahydrofuran, and 7.32 ml of a 2.7 M solution of n-butyllithium in n-hexane are added at  $-20^{\circ}C$ . After 1 hour of stirring at  $-20^{\circ}C$ , 4.36 g of [cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]acetaldehyde, dissolved in 40 ml of tetrahydrofuran, are added dropwise. The reaction mixture is slowly warmed to room temperature. 50 ml of water are then added, and the mixture is extracted three times with in each case 200 ml of ethyl acetate. The combined organic phases are dried over magnesium sulfate and the solvent is then removed under reduced pressure. The residue is purified on silica gel using the mobile phase n-heptane:ethyl acetate = 30:1. This gives 3.11 g of tert-butyl 4-[cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]-2-ethylbut-2-enoate as an oil.  $C_{32}H_{46}O_3Si$  (506.81),  $R_f$ (n-heptane:ethyl acetate = 5:1) = 0.73.

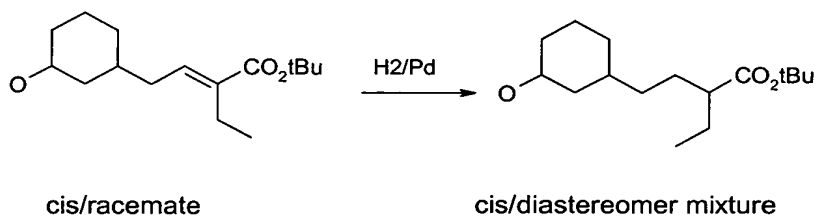
tert-Butyl 2-ethyl-4-(cis-3-hydroxycyclohexyl)but-2-enoate



1.3.11 g of tert-butyl 4-[cis-3-(tert-butyl-diphenylsilyloxy)cyclohexyl]-2-ethylbut-2-enoate are dissolved in 20 ml of tetrahydrofuran, and 15.7 ml of a 1M solution of tetrabutylammonium fluoride in tetrahydrofuran are added. The mixture is stirred at 60°C for 2 hours. The reaction mixture is concentrated under reduced pressure and purified on silica gel using the mobile phase n-heptane:ethyl acetate = 30:1 => ethyl acetate. This gives 1.65 g of tert-butyl 2-ethyl-4-(cis-3-hydroxycyclohexyl)but-2-enoate as an oil.  $\text{C}_{16}\text{H}_{28}\text{O}_3$  (268.40),  $R_f(\text{n-heptane:ethyl acetate} = 5:1) = 0.07$ .

10

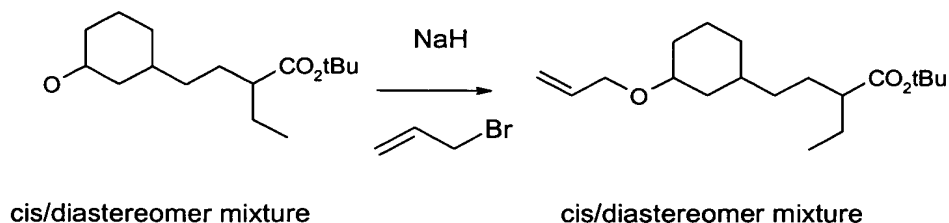
tert-Butyl 2-ethyl-4-(cis-3-hydroxycyclohexyl)butyrate



15 1.65 g of tert-butyl 2-ethyl-4-(cis-3-hydroxycyclohexyl)but-2-enoate are dissolved in 50 ml of methanol, and 100 mg of Perlman's catalyst are added. The mixture is stirred under an atmosphere of hydrogen for 24 hours. The catalyst is filtered off through Celite, and the filtrate is then concentrated under reduced pressure. This gives 1.49 g of tert-butyl 2-ethyl-4-(cis-3-hydroxycyclohexyl)butyrate as a colorless oil.  $\text{C}_{16}\text{H}_{30}\text{O}_3$  (270.40),  $R_f(\text{n-heptane:ethyl acetate} = 5:1) = 0.10$ .

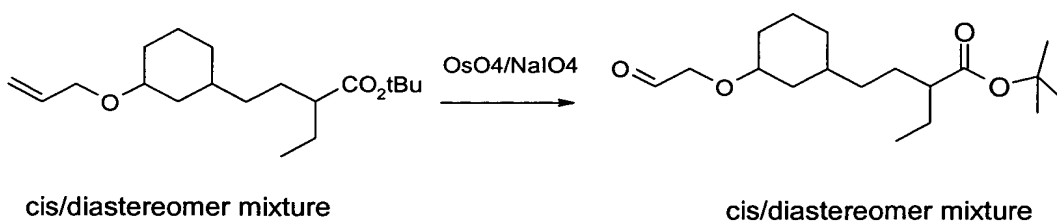
20

tert-Butyl 4-(cis-3-allyloxycyclohexyl)-2-ethylbutyrate



- 1.19 g of tert-butyl 2-ethyl-4-(cis-3-hydroxycyclohexyl)butyrate are dissolved in 50 ml of dimethylformamide, and 210 mg of sodium hydride (60% strength in paraffin oil) are added. The suspension is stirred at room temperature for 15 minutes, and 1.6 ml of allyl bromide are then added. After one hour, a further 320 mg of sodium hydride are added. After 12 hours of stirring at room temperature, another 320 mg of sodium hydride and then 1.6 ml of allyl bromide are metered in. Stirring at room temperature is continued for a further 12 hours.
- After addition of 200 ml of methyl tert-butyl ether, the mixture is washed three times with in each case 100 ml of water and the organic phase is separated off and dried over magnesium sulfate. The solvent is removed under reduced pressure. The residue is purified on silica gel using the mobile phase n-heptane:ethyl acetate = 60:1 => 30:1. This gives 770 mg of tert-butyl 4-(cis-3-allyloxycyclohexyl)-2-ethylbutyrate as an oil.  $C_{19}H_{34}O_3$  (310.48),  $R_f$ (n-heptane:ethyl acetate = 5:1) = 0.48.

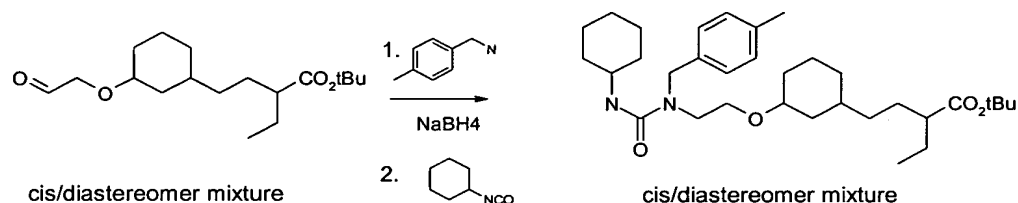
tert-Butyl 2-ethyl-4-[cis-3-(2-oxoethoxy)cyclohexyl]butyrate



- 770 mg of tert-butyl 4-(cis-3-allyloxycyclohexyl)-2-ethylbutyrate are dissolved in 50 ml of diethyl ether, and 1.59 g of sodium periodate, dissolved in 50 ml of water, are added. At 0°C, 2.56 ml of an osmium tetroxide solution (2.5% by weight in tert-butanol) are added, and the mixture is stirred vigorously at room temperature.
- After 9 hours, a further 12.8 ml of the osmium tetroxide solution are added, and

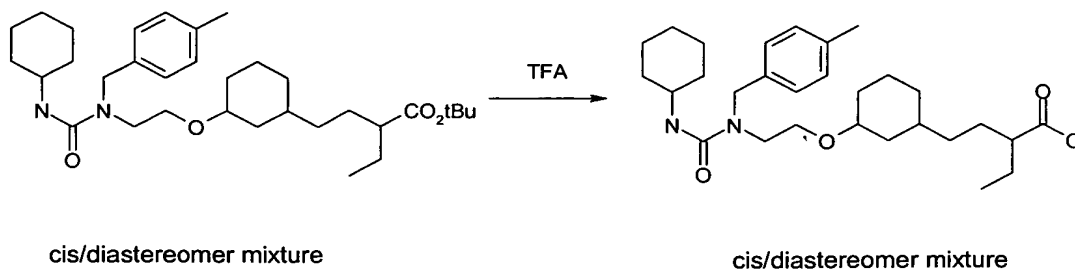
stirring at room temperature is continued for a further 3 hours. 200 ml of methyl tert-butyl ether are added and the mixture is washed with a saturated sodium thiosulfate solution. The organic phase is dried over magnesium sulfate and the solvent is then removed under reduced pressure. This gives 710 mg of tert-butyl 2-ethyl-4-[cis-3-(2-oxoethoxy)cyclohexyl]butyrate as a yellow-brown oil.  $C_{18}H_{32}O_4$  (312.45),  $R_f$ (n-heptane:ethyl acetate = 5:1) = 0.15.

tert-Butyl 4-(cis-3-{2-[3-cyclohexyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)-2-ethylbutyrate



380 mg of the aldehyde tert-butyl 2-ethyl-4-[cis-3-(2-oxoethoxy)cyclohexyl]butyrate and 0.14 ml of 4-methylbenzylamine are dissolved in 5 ml of methanol. 400 mg of 4 Å molecular sieve, which had been dried by heating, is added, and the mixture is stirred at room temperature for two hours. 55 mg of sodium borohydride are then added to the reaction mixture. After 30 minutes, the molecular sieve is removed by filtration of the mixture through Celite. The filtrate is concentrated under reduced pressure. The residue is dissolved in 8 ml of dimethylformamide, and 0.11 ml of cyclohexyl isocyanate is added. After 12 hours, the dimethylformamide is removed under reduced pressure and the residue is purified on silica gel using the mobile phase n-heptane:ethyl acetate = 9:1 => 7:1. This gives 160 mg of the urea tert-butyl 4-(cis-3-{2-[3-cyclohexyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)-2-ethylbutyrate as an oil.  $C_{33}H_{54}N_2O_4$  (542.81), MS(ESI): 543 ( $M + H^+$ ).

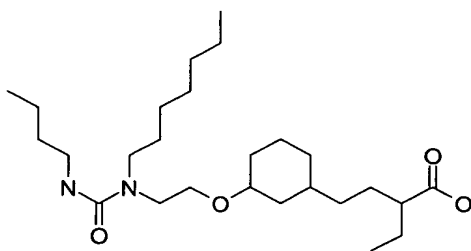
4-(cis-3-{2-[3-cyclohexyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)-2-ethylbutyric acid



160 mg of tert-butyl 4-(cis-3-{2-[3-cyclohexyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)-2-ethylbutyrate are dissolved in 16 ml of dichloromethane, and 4 ml of trifluoroacetic acid are added. The mixture is stirred at room temperature for 12 hours. 50 ml of toluene are then added, and the solvents are removed under reduced pressure. The residue is purified by RP-HPLC. Freeze drying gives 123 mg of 4-(cis-3-{2-[3-cyclohexyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)-2-ethylbutyric acid as a colorless oil.  $C_{29}H_{46}N_2O_4$  (486.70), MS(ESI): 487 ( $M + H^+$ ).

## Example 2

Analogously to Example 1, tert-butyl 2-ethyl-4-[cis-3-(2-oxoethoxy)cyclohexyl]butyrate, heptylamine and butyl isocyanate gave 4-{cis-3-[2-(3-butyl-1-heptylureido)ethoxy]cyclohexyl}-2-ethylbutyric acid.

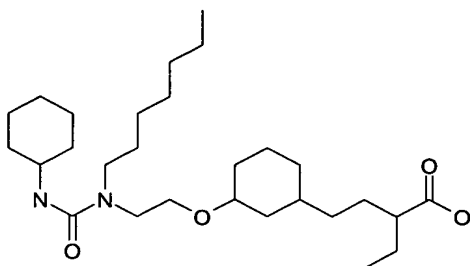


cis/diastereomer mixture

$C_{26}H_{50}N_2O_4$  (454.70), MS(ESI): 455 ( $M + H^+$ ).

**Example 3**

Analogously to Example 1, tert-butyl 2-ethyl-4-[cis-3-(2-oxoethoxy)cyclohexyl]butyrate, heptylamine and cyclohexyl isocyanate gave 4-{cis-3-[2-(3-cyclohexyl-1-heptylureido)ethoxy]cyclohexyl}-2-ethylbutyric acid.



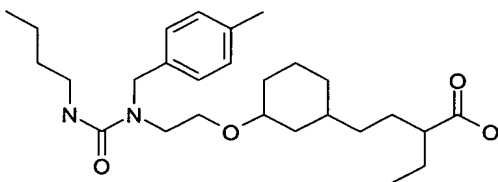
cis/diastereomer mixture

$C_{28}H_{52}N_2O_4$  (480.74), MS(ESI): 481 ( $M + H^+$ ).

10

**Example 4**

Analogously to Example 1, tert-butyl 2-ethyl-4-[cis-3-(2-oxoethoxy)cyclohexyl]butyrate, p-methylbenzylamine and butyl isocyanate gave 4-(cis-3-{2-[3-butyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)-2-ethylbutyric acid.

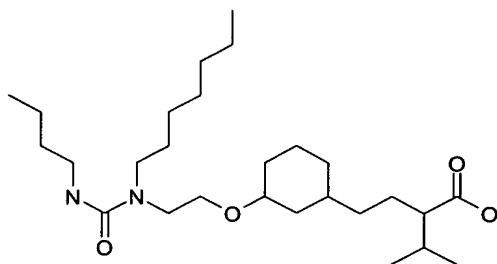


cis/diastereomer mixture

$C_{27}H_{44}N_2O_4$  (460.66), MS(ESI): 461 ( $M + H^+$ ).

**Example 5**

- Analogously to Example 1, tert-butyl diethylphosphonoacetate, isopropyl iodide,  
 [cis-3-(tert-butyl-diphenylsilyloxy)cyclohexyl]acetaldehyde, heptylamine and  
 5 butyl isocyanate gave 2-(2-{cis-3-[2-(3-butyl-1-  
 heptylureido)ethoxy]cyclohexyl}ethyl)-3-methylbutyric acid.

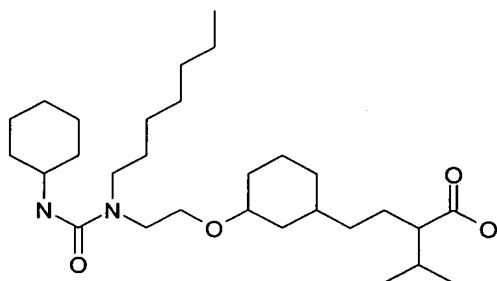


cis/diastereomer mixture

- 10  $C_{27}H_{52}N_2O_4$  (468.73), MS(ESI): 469 ( $M + H^+$ ).

**Example 6**

- Analogously to Example 1, tert-butyl diethylphosphonoacetate, isopropyl iodide,  
 15 [cis-3-(tert-butyl-diphenylsilyloxy)cyclohexyl]acetaldehyde, heptylamine and  
 cyclohexyl isocyanate gave 2-(2-{cis-3-[2-(3-cyclohexyl-1-  
 heptylureido)ethoxy]cyclohexyl}ethyl)-3-methylbutyric acid.



cis/diastereomer mixture

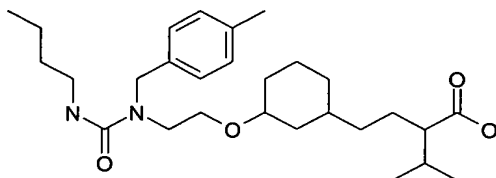
20

- $C_{29}H_{54}N_2O_4$  (494.76), MS(ESI): 495 ( $M + H^+$ ).



**Example 7**

- Analogously to Example 1, tert-butyl diethylphosphonoacetate, isopropyl iodide,  
 [cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]acetaldehyde, p-benzylamine and  
 5 butyl isocyanate gave 2-[2-(cis-3-{2-[3-butyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)ethyl]-3-methylbutyric acid.

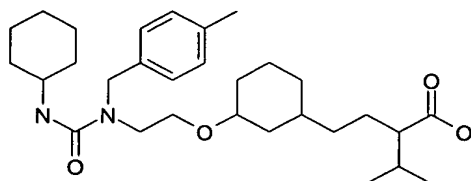


cis/diastereomer mixture

- 10  $C_{28}H_{46}N_2O_4$  (474.69), MS(ESI): 475 ( $M + H^+$ ).

**Example 8**

- Analogously to Example 1, tert-butyl diethylphosphonoacetate, isopropyl iodide,  
 15 [cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]acetaldehyde, p-methylbenzylamine  
 and cyclohexyl isocyanate gave 2-[2-(cis-3-{2-[3-cyclohexyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)ethyl]-3-methylbutyric acid.



cis/diastereomer mixture

20

- $C_{30}H_{48}N_2O_4$  (500.73), MS(ESI): 501 ( $M + H^+$ ).

**Example 9**

- 25 tert-Butyl 4-[cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]but-2-enoate

5  
10

The reaction scheme shows the hydrogenation of a cyclohexyl allyl ester derivative. The starting material is a cyclohexane ring with a *tert*-butyldimethylphenylsilyloxy group and an allyl ester group ( $\text{CH}_2\text{CH}=\text{CHCO}_2\text{tBu}$ ). The reaction is catalyzed by  $\text{H}_2/\text{Pd}$ . The product is a cyclohexane ring with the same *tert*-butyldimethylphenylsilyloxy group and a propyl ester group ( $\text{CH}_2\text{CH}_2\text{CH}_2\text{CO}_2\text{tBu}$ ).

Starting material: *cis*/diastereomer mixture

Reagent:  $\text{H}_2/\text{Pd}$

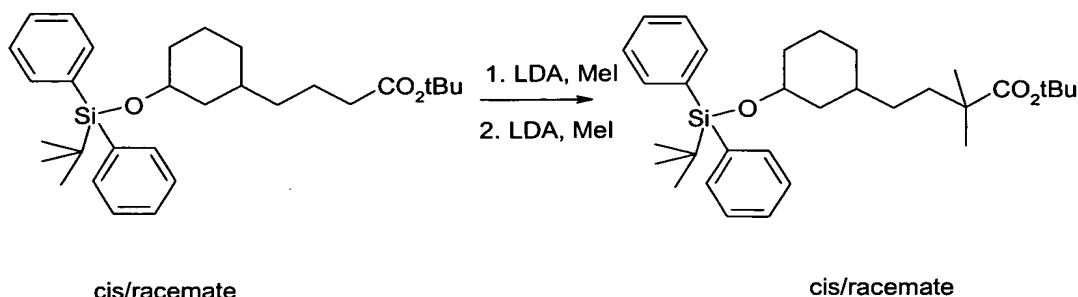
Product: *cis*/racemate

20

butyl-diphenylsilanyloxy)cyclohexyl]butanoate as an oil.  $C_{30}H_{44}O_3Si$  (480.75), MS(ESI): 481 ( $M+H^+$ ).

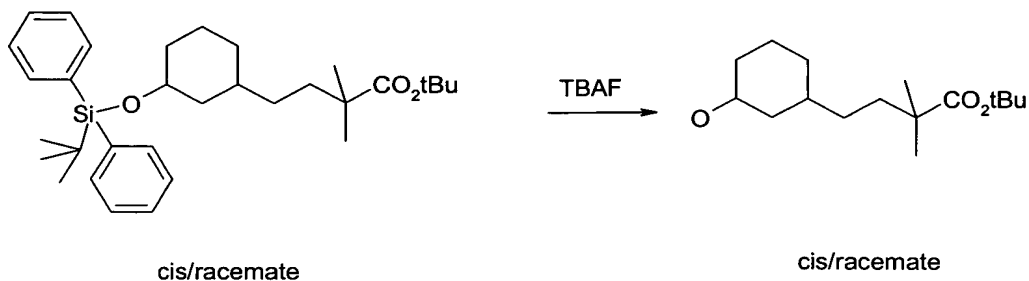
tert-Butyl 4-[cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]-2,2-dimethylbutyrate

5



2 g of tert-butyl 4-[cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]butanoate are dissolved in 20 ml of tetrahydrofuran, and 3.1 ml of a 2M solution of lithium diisopropylamide in tetrahydrofuran are added at  $-78^{\circ}C$ . The reaction mixture is stirred at  $-78^{\circ}C$  for 2 hours and then warmed to  $-30^{\circ}C$ , and 1.6 ml of methyl iodide are added. The mixture is allowed to warm to room temperature over a period of 12 hours. The reaction mixture is then diluted by addition of 150 ml of methyl tert-butyl ether and washed with saturated sodium chloride solution. The organic phase is dried over magnesium sulfate and the solvent is removed under reduced pressure. The residue is purified on silica gel using the mobile phase n-heptane:ethyl acetate = 10:1. This gives 2.1 g of the monomethylated product. This product is dissolved in 20 ml of tetrahydrofuran, and 6 ml of a 2M solution of lithium diisopropylamide in tetrahydrofuran are added at  $-78^{\circ}C$ . The reaction mixture is stirred at  $-78^{\circ}C$  for 2 hours and then warmed to  $0^{\circ}C$ , and, after 10 minutes at  $0^{\circ}C$ , 2.5 ml of methyl iodide are added. The mixture is allowed to warm to room temperature over a period of 12 hours. The reaction mixture is then diluted by addition of 150 ml of methyl tert-butyl ether and washed with saturated sodium chloride solution. The organic phase is dried over magnesium sulfate and the solvent is then removed under reduced pressure. The residue is purified on silica gel using the mobile phase n-heptane:ethyl acetate = 10:1. This gives 1.8 g of tert-butyl 4-[cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexyl]-2,2-dimethylbutyrate as an oil.  $C_{32}H_{48}O_3Si$  (508.82),  $R_f$ (n-heptane:ethyl acetate = 5:1) = 0.49.

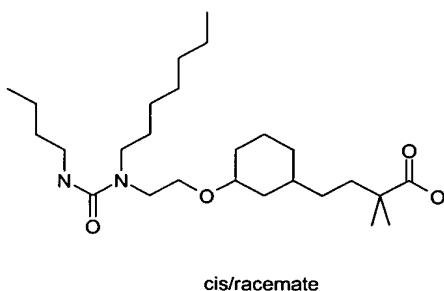
## tert-Butyl 4-(cis-3-hydroxycyclohexyl)-2,2-dimethylbutyrate



5

2 g of tert-butyl 4-[cis-3-(tert-butyl-diphenylsilyloxy)cyclohexyl]-2,2-dimethylbutyrate are dissolved in 10 ml of tetrahydrofuran, and 8 ml of a 1 M solution of tetrabutylammonium fluoride and tetrahydrofuran are added. The mixture is stirred at 60°C for 2 hours. The reaction mixture is concentrated under reduced pressure and purified on silica gel using the mobile phase n-heptane:ethyl acetate = 20:1 => 1:1. This gives 730 mg of tert-butyl 4-[cis-3-hydroxycyclohexyl]-2,2-dimethylbutyrate as an oil.  $C_{16}H_{30}O_3$  (270.42),  $R_f$ (n-heptane:ethyl acetate = 5:1) = 0.22.

- 15 Analogously to Example 1, tert-butyl 4-(cis-3-hydroxycyclohexyl)-2,2-dimethylbutyrate, p-heptylamine and butyl isocyanate gave 4-{cis-3-[2-(3-butyl-1-heptylureido)ethoxy]cyclohexyl)-2,2-dimethylbutyric acid.

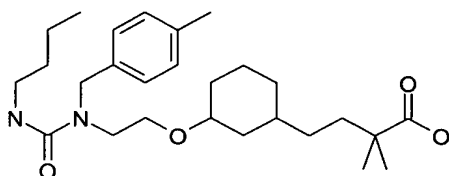


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$C_{26}H_{50}N_2O_4$  (454.70), MS(ESI): 455 ( $M + H^+$ ).

**Example 10**

Analogously to Example 9, tert-butyl 4-(cis-3-hydroxycyclohexyl)-2,2-dimethylbutyrate, p-methylbenzylamine and butyl isocyanate gave 4-(cis-3-{2-[3-butyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)-2,2-dimethylbutyric acid.



cis/racemate

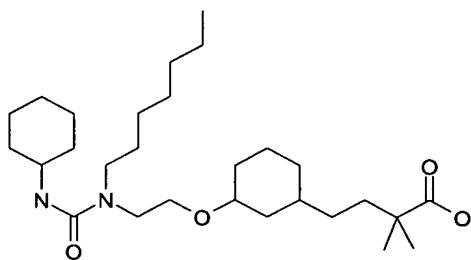
$C_{27}H_{44}N_2O_4$  (460.66), MS(ESI): 461 ( $M + H^+$ ).

10

**Example 11**

Analogously to Example 9, tert-butyl 4-(cis-3-hydroxycyclohexyl)-2,2-dimethylbutyrate, p-heptylamine and cyclohexyl isocyanate gave 4-{cis-3-[2-(3-cyclohexyl-1-heptylureido)ethoxy]cyclohexyl}-2,2-dimethylbutyrate.

15



cis/racemate

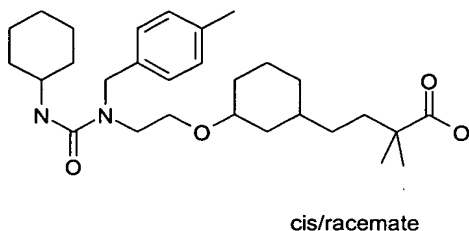
$C_{28}H_{52}N_2O_4$  (480.74), MS(ESI): 481 ( $M + H^+$ ).

20

**Example 12**

Analogously to Example 9, tert-butyl 4-(cis-3-hydroxycyclohexyl)-2,2-dimethylbutyrate, p-methylbenzylamine and cyclohexyl isocyanate gave 4-(cis-3-

{2-[3-cyclohexyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexyl)-2,2-dimethylbutyric acid.

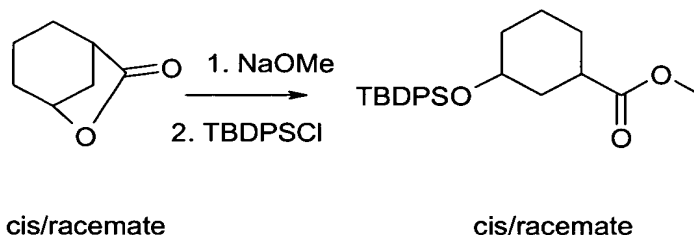


5

C<sub>29</sub>H<sub>46</sub>N<sub>2</sub>O<sub>4</sub> (486.70), MS(ESI): 487 (M + H<sup>+</sup>).

### Example 13

#### 10 Methyl cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexanecarboxylate

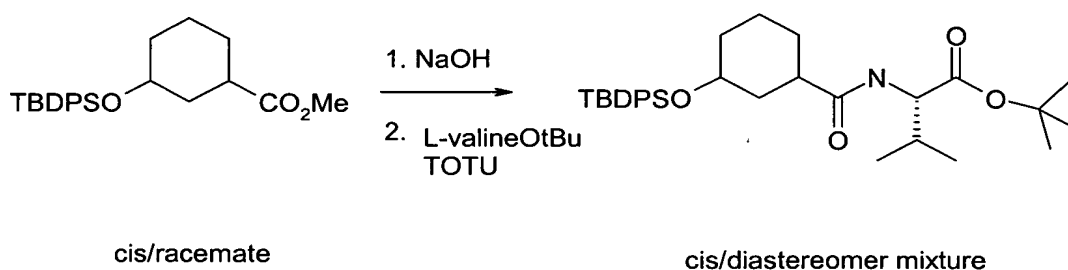


- 22 g of 6-oxabicyclo[3.2.1]octan-7-one are dissolved in 200 ml of methanol, and
- 15 10% strength sodium methoxide solution is added until a pH of 10 is reached. The mixture is stirred at room temperature for 30 minutes and then neutralized by addition of dilute acetic acid, and the mixture is concentrated under reduced pressure. The residue is dissolved in ethyl acetate, dried over magnesium sulfate and then concentrated under reduced pressure. This gives 21 g of the methyl
- 20 ether as a colorless oil. This is dissolved in 200 ml of dimethylformamide, 43 g of tert-butyldiphenylsilyl chloride, 13 g of imidazole and 1 g of dimethylaminopyridine are added and the mixture is stirred at room temperature for 12 hours. The solvent is removed under reduced pressure and the residue is taken up in methyl tert-butyl ether and washed with water. The organic phase is dried over magnesium sulfate
- 25 and the solvent is then removed. This gives 56.8 g of methyl cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexanecarboxylate as a yellow oil.

$C_{24}H_{32}O_3Si$  (396.61), MS(ESI): 397 ( $M+H^+$ ).

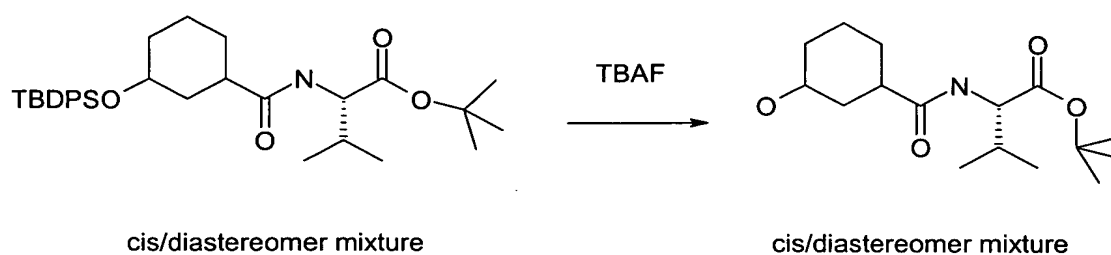
tert-Butyl cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexanecarbonyl]amino}-(3S)-methylbutyrate

5



36.8 g of cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexanecarboxylic acid are dissolved in 150 ml of isopropanol, and 8 g of sodium hydroxide, dissolved in 50 ml of water, are added. The mixture is heated at 60°C for 1 hour. The reaction mixture is cooled and neutralized by addition of 2N hydrochloric acid. The reaction mixture is concentrated under reduced pressure and extracted with in each case 200 ml of ethyl acetate. The combined organic phases are dried over magnesium sulfate and the solvent is then removed under reduced pressure. This gives 34 g of the free acid as a colorless oil ( $R_f(\text{ethyl acetate}) = 0.63$ ). This is dissolved in 250 ml of dimethylformamide, and 18.6 g of *tert*-butyl L-valinate hydrochloride are added. At 0°C, 29.1 g of O-[cyano(ethoxycarbonyl)methyleneamino]-1,1,3,3,-tetramethyluronium tetrafluoroborate are added. After 10 minutes, the ice bath is removed and 23.9 g of hydroxybenzotriazole and 61.8 ml of Hünig base are added. The mixture is stirred at room temperature for 2 hours. The solvent is removed under reduced pressure and the resulting residue is dissolved in ethyl acetate and washed three times with saturated sodium bicarbonate solution. The organic phase is dried over magnesium sulfate and the solvent is then removed. The residue is purified on silica gel using the mobile phase *n*-heptane:ethyl acetate = 2:1. This gives 43.0 g of tert-butyl 2-[[cis-3-(tert-butyl-diphenylsilanyloxy)cyclohexanecarbonyl]-amino}-(3S)-methylbutyrate as a yellow oil.  $C_{32}H_{47}NO_4Si$  (537.82), MS(ESI): 538.

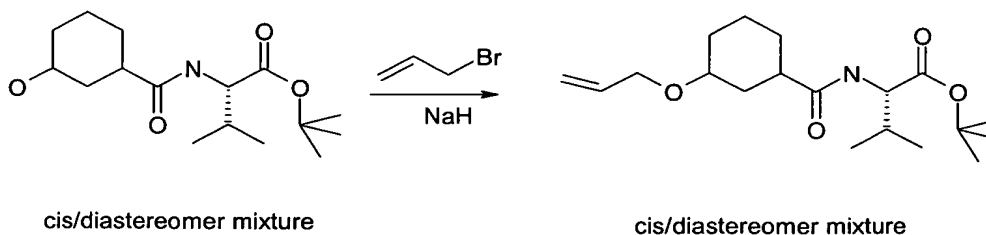
tert-Butyl 2-[(cis-3-hydroxycyclohexanecarbonyl)amino]-(3S)-methyl-butyrate



- 5 43.0 g of tert-butyl 2-[(cis-3-(tert-butyl-diphenylsilyloxy)cyclohexanecarbonyl]amino-(3S)-methylbutyrate are dissolved in 80 ml of tetrahydrofuran, and 80 ml of a 1M solution of tetrabutylammonium fluoride in tetrahydrofuran are added. The mixture is stirred at 60°C for 3 h and then concentrated under reduced pressure, and the residue is purified on silica gel using the mobile phase n-
- 10 heptane:ethyl acetate = 5:1 => 1:1. This gives 18 g of a white solid. Since this is still slightly impure, 8 g are subjected to another purification on silica gel. This gives 6.8 g of tert-butyl 2-[(cis-3-hydroxycyclohexanecarbonyl)amino]-(3S)-methylbutyrate as a white solid.  $C_{16}H_{29}NO_4$  (299.41), MS(ESI): 300 ( $M+H^+$ ).
- tert-Butyl 2-[(cis-3-hydroxycyclohexanecarbonyl)amino]-(3S)-methyl-butyrate can
- 15 be separated by chiral HPLC. This gives tert-butyl 2-[(1R,3S)-3-hydroxycyclohexanecarbonyl]amino-(3S)-methylbutyrate ( $R_t$  = 4.9 min) and tert-butyl 2-[(1S,3R)-3-hydroxycyclohexanecarbonyl]amino-(3S)-methylbutyrate ( $R_t$  = 5.7 min) as colorless lyophilisates. (Chiralpak AD/34 250 × 4.6; mobile phase n-heptane:ethanol:methanol = 20:1:1 + 0.1% trifluoroacetic acid).

20

tert-Butyl 2-[(cis-3-allyloxycyclohexanecarbonyl)amino]-(3S)-methylbutyrate



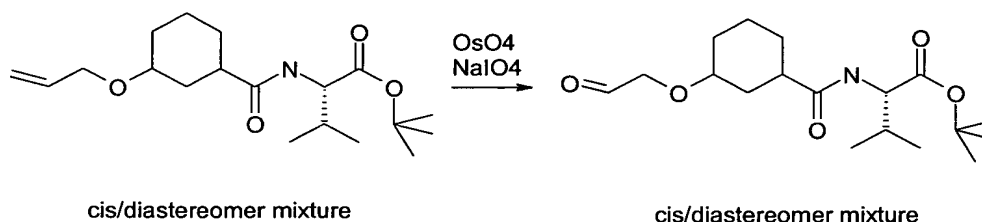


2.8 g of tert-butyl 2-[(cis-3-hydroxycyclohexanecarbonyl)amino]-(3S)-methyl butyrate are dissolved in 20 ml of dimethylformamide, and 450 mg of sodium hydride (60% strength suspension in mineral oil) are added. After 10 minutes, 3.4 ml of allyl bromide are added dropwise. After 3 hours of stirring at room

5 temperature, another 700 mg of sodium hydride are added. After 2 hours of stirring at room temperature, another 3.4 ml of allyl bromide are metered in. The mixture is stirred at room temperature for 12 hours, 200 ml of methyl tert-butyl ether are then added to the reaction mixture and the mixture is washed three times with in each case 100 ml of water. The organic phase is dried over magnesium sulfate and  
10 concentrated under reduced pressure, and the residue is purified on silica gel using the mobile phase n-heptane:ethyl acetate = 40:1 => 10:1. This gives 900 mg of tert-butyl 2-[(cis-3-allyloxycyclohexanecarbonyl)amino]-(3S)-methylbutyrate as a colorless oil.  $C_{19}H_{33}NO_4$  (339.48), MS(ESI): 340 ( $M+H^+$ ),  $R_f$ (n-heptane:ethyl acetate = 1:1) = 0.58.

15

tert-Butyl (3S)-methyl-2-[(cis-3-(2-oxoethoxy)cyclohexanecarbonyl]amino}butyrate

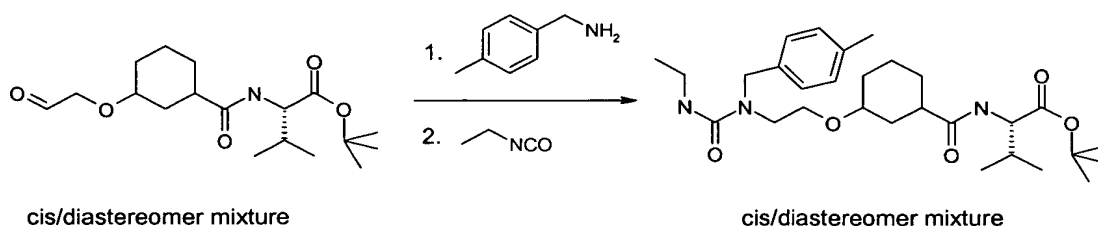


20 900 mg of tert-butyl 2-[(cis-3-allyloxy)cyclohexanecarbonyl]amino]-(3S)-methylbutyrate are dissolved in 20 ml of diethyl ether, and 1.7 g of sodium periodate, dissolved in 20 ml of water, are added. At 0°C, 1.6 ml of a solution of osmium tetroxide (2.5% by weight) in tert-butanol are added. The reaction mixture is stirred vigorously at room temperature for 3 hours. At 0°C, 50 ml of saturated  
25 sodium thiosulfate solution are then added. The organic phase is separated off. The aqueous phase is extracted three times with in each case 50 ml of methyl tert-butyl ether. The combined organic phases are dried over magnesium sulfate and the solvent is then removed under reduced pressure. This gives 1.0 g of tert-butyl (3S)-methyl-2-[(cis-3-(2-oxoethoxy)cyclohexanecarbonyl]amino}butyrate as a  
30 colorless oil which is reacted further without purification.

$C_{18}H_{31}NO_5$  (341.45),  $R_f$ (n-heptane:ethyl acetate = 1:1) = 0.19.

tert-Butyl 2-[(cis-3-{2-[3-ethyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexanecarbonyl)amino]-(3S)-methylbutyrate

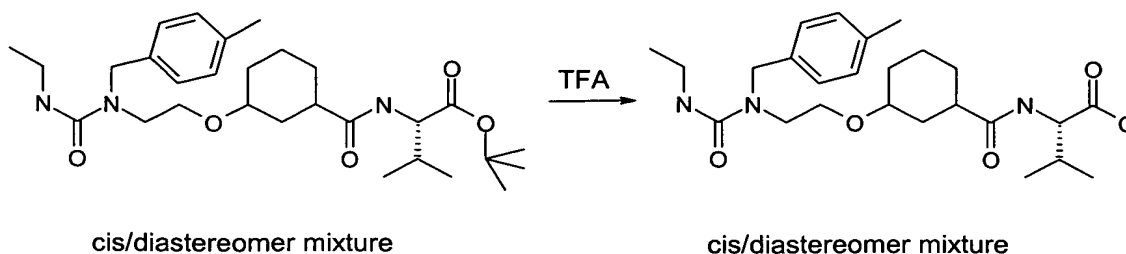
5



330 mg of tert-butyl (3S)-methyl-2-[(cis-3-(2-oxoethoxy)cyclohexanecarbonyl)amino]butyrate are dissolved in 3 ml of methanol, and 0.12 ml of 4-methylbenzylamine, dissolved in 5 ml of methanol, is added. 300 mg of molecular sieve (4 Å), which had been dried by heating, are added, and the mixture is stirred at room temperature for 2 hours. 50 mg of sodium borohydride are then added, and stirring at room temperature is continued for another 30 minutes. The molecular sieve is filtered off and the filtrate is concentrated under reduced pressure. The resulting residue is dissolved in 20 ml of dimethylformamide, and 80 µl are added. The mixture is stirred at room temperature for 12 hours. The dimethylformamide is removed under reduced pressure and the residue is purified on silica gel using the mobile phase n-heptane:ethyl acetate = 9:1 => 2:1. This gives 320 mg of tert-butyl 2-[(cis-3-{2-[3-ethyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexanecarbonyl)amino]-(3S)-methylbutyrate as a light-yellow oil.  $C_{29}H_{47}N_3O_5$  (517.72), MS(ESI): 518.

2-[(cis-3-{2-[3-Ethyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexanecarbonyl)amino]-(3S)-methylbutyric acid

25

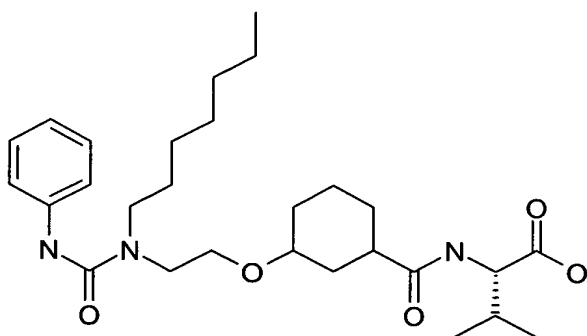


320 mg of tert-butyl 2-[(cis-3-{2-[3-ethyl-1-(4-methylbenzyl)ureido]ethoxy}-cyclohexanecarbonyl)amino]-(3S)-methylbutyrate are dissolved in 20 ml of  
 5 dichloromethane, and 10 ml of trifluoroacetic acid are added. The mixture is stirred at room temperature for 3 hours. The solvents are removed under reduced pressure and the residue is purified by RP-HPLC. This gives 115 mg of 2-[(cis-3-{2-[3-ethyl-1-(4-methylbenzyl)ureido]ethoxy}cyclohexanecarbonyl)amino]-(3S)-methylbutyric acid as a white lyophilisate.  $C_{25}H_{39}N_3O_5$  (461.61), MS(ESI): 462.

10

#### Example 14

Analogously to Example 13, tert-butyl (3S)-methyl-2-[(cis-3-(2-oxoethoxy)-cyclohexanecarbonyl)amino]butyrate, n-heptylamine and phenyl isocyanate gave  
 15 2-[(cis-3-[2-(1-heptyl-3-phenylureido)ethoxy]cyclohexanecarbonyl)amino]-(3S)-methylbutyric acid.

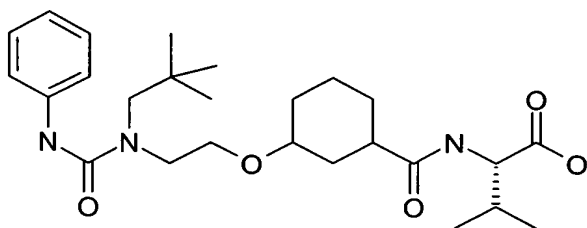


cis/diastereomer mixture

20  $C_{28}H_{45}N_3O_5$  (503.69), MS(ESI): 504.

**Example 15**

- Analogously to Example 13, tert-butyl (3S)-methyl-2-[[cis-3-(2-oxoethoxy)-cyclohexanecarbonyl]amino]butyrate, 2,2-dimethylpropylamine and phenyl isocyanate gave 2-[(cis-3-{2-[1-(2,2-dimethylpropyl)-3-phenylureido]-ethoxy}cyclohexanecarbonyl)amino]-(3S)-methylbutyric acid.



cis/diastereomer mixture

- 10  $C_{26}H_{41}N_3O_5$  (475.63), MS(ESI): 476.